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CROSS-CONNECTIONS IN CHICAGO[1]

BY ARTHUR E. GORMAN[2]

The history of American water works is marred by the record of many serious outbreaks of typhoid fever and other intestinal diseases resulting from contamination of public water supplies by polluted water which entered the distribution system through cross-connections. As an aftermath of these experiences health and water works officials in this country will now generally be found in agreement on a policy requiring a physical disconnection of the public water system from all other water systems. While the writer is in full accord with this principle for new installations, he is of the opinion that a rigid enforcement of this policy may not infrequently impose a severe hardship upon certain industries and require expenditures quite out of proportion to the potential danger to the public health. This position is taken after two years intimate contact with the work of eliminating cross connections with the Chicago water works system.

In February, 1924, under the direction of the writer, a systematic survey of cross-connections was begun by the Chicago Department of Health and is still in progress. Very much to our surprise 491 illegal connections were found in the twenty-three months ending January 1, 1926. A compilation of these connections by size and types is given in table 1.

[1] Presented before the Illinois Section meeting, March 25, 1926.

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Before demanding the breaking of cross-connections the health or water works official may well investigate the reasons for their existence. He will usually find that these may be classified in three groups:

1. Inability of the public system to supply adequate pressure or sufficient quantity of water.
2. A desire for economy.
3. Convenience of operation.

TABLE 1

SIZE	TYPE OF CROSS CONNECTION		TOTAL	PER CENT OF TOTAL
	Direct	Indirect		
inches				
½	4	17	21	4.3
¾	22	31	53	10.8
1	13	19	32	6.5
1¼	4	34	38	7.7
1½	11	7	18	3.7
2	48	57	105	21.4
2½	10	8	18	3.7
3	25	32	57	11.6
3½	1	0	1	0.2
4	32	37	69	14.0
5	1	0	1	0.2
6	13	24	37	7.5
8	4	10	14	2.9
10	1	3	4	0.8
12	3	11	14	2.9
14	0	3	3	0.6
15	1	1	2	0.4
16	0	2	2	0.4
18	1	1	2	0.4
Total.....	194	297	491	100.0

Obviously, in cases where the public water works system cannot render adequate service, the consumer's problem is entitled to every consideration consistent with safety to the public health; in fact, the success of any campaign against cross connections will depend to no small degree upon the attitude of the health or water department in cases of this kind.

Cross-connections in large buildings and industrial plants cannot ordinarily be removed immediately without incurring risks to life and property, and the problem of the consumer in these cases is no

slight matter. It has been our experience in Chicago that by taking proper precautionary measures in the meantime, a patient attitude on the part of the public official will result in an early compliance with recommendations. It must be borne in mind that in many cases the expense involved is considerable and that those in immediate charge must obtain permission from general managers, or even Boards of Directors, before full compliance can be effected. In the instance of one large company in Chicago, which was being operated under the direction of a receiver appointed by the Federal court, it was necessary to obtain authority from the court to incur expenditures found necessary to make equivalent substitution for a dangerous cross-connection.

Where a dual water system is used merely for the sake of economy, the public supply being cross-connected for use in emergencies, the conditions are entirely reversed and the demand for an immediate separation from the city water system is not unreasonable. In such cases the safety of the public water supply may have been continuously in jeopardy while the city stood ready to give emergency service to the private consumer, for which its remuneration might be insignificant.

Cross-connections of convenience should never be tolerated.

In Chicago cross-connections are divided into two classes:

1. *Direct cross-connections*—where there is or may be a differential pressure between the two systems, permitting a flow from the secondary system into the city water lines in case of leakage past a valve or valves.

2. *Indirect cross-connections*—where the two systems are physically connected, but prevailing conditions are such that the possibility of flow from the secondary system into the city water lines are extremely remote.

A physical separation of the two systems has always been requested where direct cross-connections were found. The justice of this stand has been uniformly recognized and with a few exceptions prompt compliance with the regulation of the Department of Public Works, forbidding cross-connections, has followed the official notification. This regulation, which appears in the Rules and Regulations governing service pipe installations, issued by the Division of Water Pipe Extension, Bureau of Engineering is as follows:

> Wherever a system of water supply piping is installed either inside or outside of buildings, in streets or alleys or other public or private property which

receives its supply from any well, cistern, river, pond, lake or any other source except the water supply system of the city, such systems shall be kept entirely separate from and no connections of any kind, either direct or indirect, shall be made with any pipe or system of piping which receives its supply from the water supply system of the city.

Early in the campaign the department made a valuable contact with the Chicago Board of Fire Underwriters, whose chief engineer adopted a policy which is not only legally sound, but also has been of material assistance in certain cases where stubborn resistance was anticipated. He advised that where the Underwriters had allowed credit on the insurance rate for the existence of an illegal connection with the public water system, this credit would be removed when notification of the illegal cross-connection was received.

The cross-connection investigation was not confined to connections between secondary water systems and the public water supply, but was extended to all types of connections through which water used by the public might be exposed to contamination. This led into a special study of swimming pools, house filters, ice plants, condensers, underground reservoirs, roof tanks and many other water systems common to modern standards of living and to industries where large quantities of water are consumed.

As sewage is the most important source of infection, special attention was given to connections between water systems and waste connections to sewers. This phase of our problem was a particularly acute one because in certain sections of Chicago the capacity of the sewer system is inadequate and following heavy rainfalls serious flooding is a frequent occurrence. The public health officer in a city where the sewer system is inadequate may well consider all points below the elevation of flood level in sewers as a zone of potential pollution and be governed accordingly. Obviously the manufacture of ice or the storage of food supplies in places below sewer grade in districts subject to flood is jeopardizing the public health.

While it is self-evident that the health and water departments should coöperate fully to safeguard the public water supply, it is my opinion that there can and should be established definite limits of responsibility for these two agencies. It is my belief that the water department should be responsible for the sanitary quality and safety of the public water supply up to the point of delivery to the consumer, either to the curb line or to the inside of the meter. Therefore, this department should be responsible for all cross-connections with the

public water distribution system. On the other hand, the uses which are made of water by consumers, and the handling and exposure of this water after delivery to the meter, are matters of concern to the health department, since the health of large groups of persons may be so jeopardized. For example:

The water supply to a large hotel as delivered is safe. The hotel management, for reasons of its own, elects to filter this water through pressure filters and to store it in an open cooling tank located in the basement, from which tank the chilled water is re-circulated throughout the hotel by special pumping units (see figure 3). Sewage from an overhead house line, passing through the basement, drips into

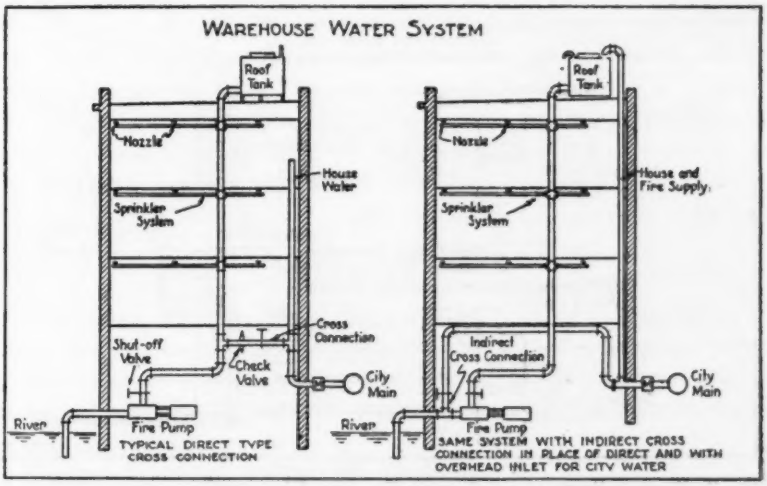

FIG. 1. WAREHOUSE WATER SYSTEM

the tank, with the result that a severe outbreak of diarrhoea develops among patrons of the hotel. The water department is, in my opinion, in no way to blame, responsibility for the water system within the hotel being a function of the health department.

Although the Chicago survey developed a myriad of cross-connection conditions which had to be worked on individually, in accordance with the local details, I have chosen to illustrate by diagrammatic sketches typical cases which are considered of special importance.

Figure 1 is typical of a great many cross-connections found at warehouses located along the Chicago and Calumet rivers and their

tributaries. The cross-connections in these cases were usually made through carelessness or with the object of saving the expense of a special city water line to the roof tank, which expense, of course, had to be met later to give the protection desired.

Where difficulty with clogging of the river suction to the fire pump was experienced the indirect type of cross-connection shown to the left was not objected to provided the fire pump was of the reciprocating type. In case the fire pump was a centrifugal pump the indirect cross-connection was not permitted during the winter season when dangers of freezing of the river suction existed. Note also that

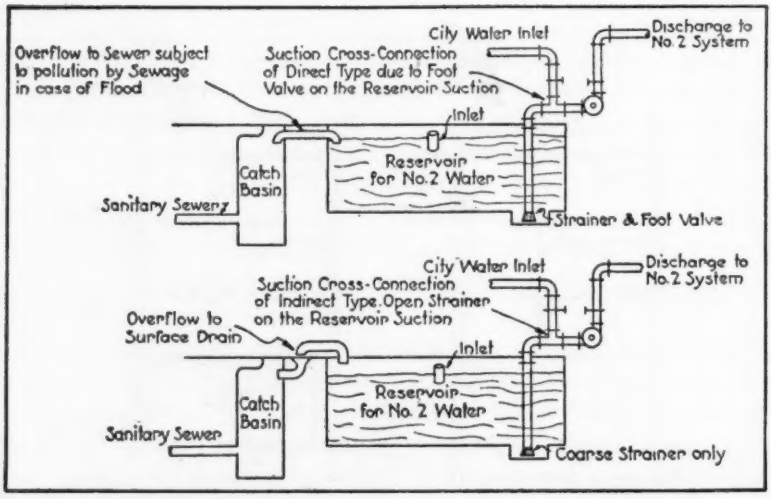
Overflow to Sewer subject to pollution by Sewage in case of Flood
Suction Cross-Connection of Direct Type due to Foot Valve on the Reservoir Suction
City Water Inlet
Discharge to No. 2 System
Inlet
Reservoir for No. 2 Water
Catch Basin
Sanitary Sewer
Strainer & Foot Valve
City Water Inlet
Discharge to No. 2 System
Suction Cross-Connection of Indirect Type. Open Strainer on the Reservoir Suction
Overflow to Surface Drain
Inlet
Reservoir for No. 2 Water
Catch Basin
Sanitary Sewer
Coarse Strainer only

FIG. 2. WATER SYSTEM AT LARGE PLANTS WHERE CONDENSER WATER IS COLLECTED FOR RE-USE AND MISCELLANEOUS SECOND USES

no valve is permitted between the pump and the river suction, so that contaminated water from the roof tank cannot enter the indirect cross-connection to the city main.

Figure 2 illustrates another type of indirect cross-connection not objected to in cases where the supply of city water is inadequate. The system illustrated is typical of many existing at packing plants in the Union Stock Yards where water which is passed over condensers is collected in reservoirs and re-used in what is called the No. 2 system. This water may be re-used in the condensers or pumped to various plants for general washing and cleaning purposes, where the quality of the water is not of prime importance. The No. 2 system

is also essentially the emergency reserve for fire fighting purposes. To require a separation of these indirect cross-connections would cost the companies concerned many thousands of dollars, which expense would be out of proportion to the risk to the public health involved. In several cases dangerous connections were found, and it may be said to the credit of the companies concerned that they acted promptly to correct them. Of course, where the pump in the No. 2 system was of the centrifugal type, and the suction from the reservoir was equipped with a foot valve for priming purposes, what appeared to be an indirect cross-connection was in reality a direct cross-connection. In these cases removal of the foot valve

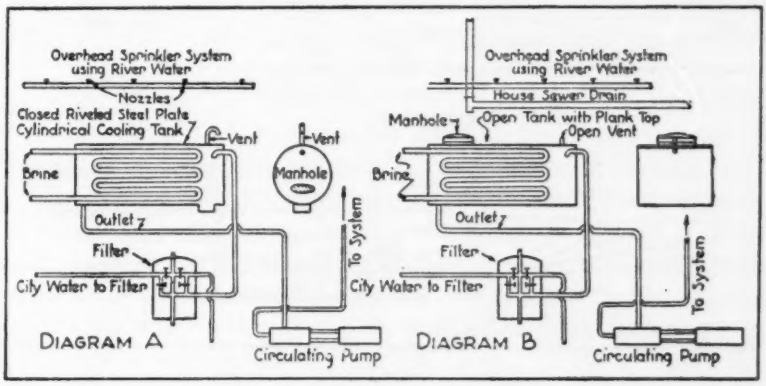

FIG. 3

Diagram A. House tanks or surge tanks should not be open at the top; vents should turn downward.

Diagram B. House water system exposed to overhead sources of pollution. This system is also typical of many with open surge tank installations.

and any valves between the reservoir suction and the centrifugal pump was required. Overflow connections to sewers were altered, as shown in the diagram, so that the possibility of sewage flowing back into the reservoir was eliminated.

Figure 3 illustrates a typical installation where city water is stored in a tank and re-circulated within a building or plant. In a number of plants open surge tanks were used without due care being taken to see that there were no sources of contamination above the tank. In general, the use of open tanks is to be discouraged in favor of closed tanks properly vented. In any case before the location of a storage tank is selected it should be made certain that the water in

the tank will not be affected by possible leakage from a sewer drain or sprinkler water from the fire system.

Figure 4 is typical of the swimming pool installation in many institutions in Chicago. To begin with it should be noted that the swimming pool and the filters are directly connected to the sewer and located below the flood level. These conditions are open invitations to trouble in case of leaking valves. In one institution a report was received that following heavy rain storms sewage had even backed up through the floor drains under shower baths.

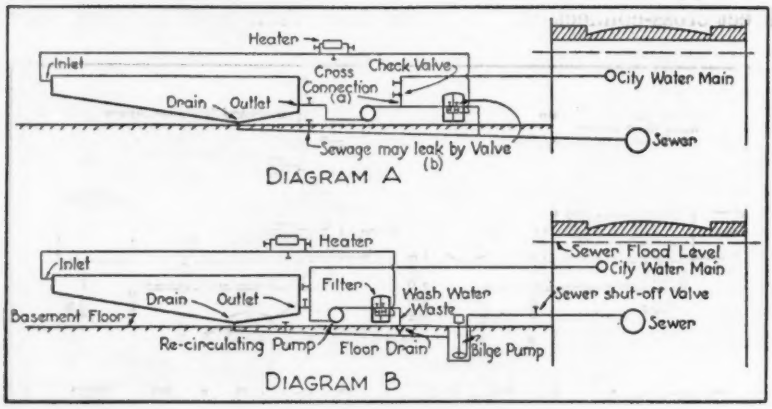

FIG. 4

Diagram A. Common type of water supply and drainage system for basement swimming pool with re-circulating equipment. *a*, cross-connection between city and re-circulating water systems; *b*, filter and pool subject to pollution by flood water from sewers.

Diagram B. Thompson water supply and drainage system for swimming pools with re-circulating equipment. *a*, no cross connections; *b*, filters and pool protected against back water from sewers.

To eliminate these direct connections with sewers the Department of Health recommends that all drainage from swimming pools, and the wash-water from filters, discharge into open sump or bilge tanks and that this waste water be re-pumped to the sewers. Of course, to prevent the flooding of the basement the discharge line to the sewer should be equipped with a shut-off valve.

In Chicago it is very common for large office and apartment buildings to filter the city water supply, using pressure filters. Frequently these filters are located in the basement and the wash-water waste line from the filter is directly connected to the sewer system. Where

such conditions exist flooding of the sewer might result in gross pollution of the filter in case of a leaky valve. It has been the policy of the department to require filter waste lines to discharge either into open floor drains or into a funnel opening connected to the drain. It is the opinion of the writer that architects and designers should give more attention to the location and design of swimming pools and pressure filter units. Where practical these tanks should be located above flood level in the sewer system.

Attention is directed to the cross-connection shown between the city water system and the re-circulated water in the swimming pool system. Such connections were found to be common practice. As a rule pressure in the re-circulating system is not over 20 pounds per square inch and most of the time the city pressure is in excess of this; however, there are periods when the reverse would be true and if valves are not tight re-circulated water might enter the city system. This cross-connection is apparently made to permit washing of the filter with the city water and to allow for filtering of the city water used for filling the tank or for make-up purposes. Where such cases existed the Department of Health recommended a change in piping connections so that the city water instead of being connected on the discharge of the re-circulating pump is connected on the suction. This system was developed in Chicago by Plumbing Inspector John R. Thompson and has met with general favor. It will be noted that back-pressure against the city water mains is not possible, on account of the open swimming pool "floating on the line." With this system, however, all water must pass through the re-circulating pump. The filters can still be washed under city pressure, the wash-water passing through the re-circulating pump. It might be necessary to arrange to disconnect the drive shaft at the motor on the re-circulating unit or to change the type of motor to permit the operation of the pump under the change of conditions.

Another common type of cross-connection in Chicago is between hot water and boiler feed systems and the city mains. Since only city water is used in these systems the danger to the public health is reasonably remote providing no injurious foreign substances are used for treating the water within the building; however, in any case there is need for protecting the meter against exposure to hot water on account of the danger of warping of the hard rubber parts in the meter. Figure 5 illustrates a piping system to a hot water heater, which was found, upon investigation, to be the cause for a complaint

of blue water coming from the taps within the building. At the address referred to there were three stores. The city water entered in the basement of the owner's store and each tenant's space was equipped with a small hot water system, as shown in the diagram.

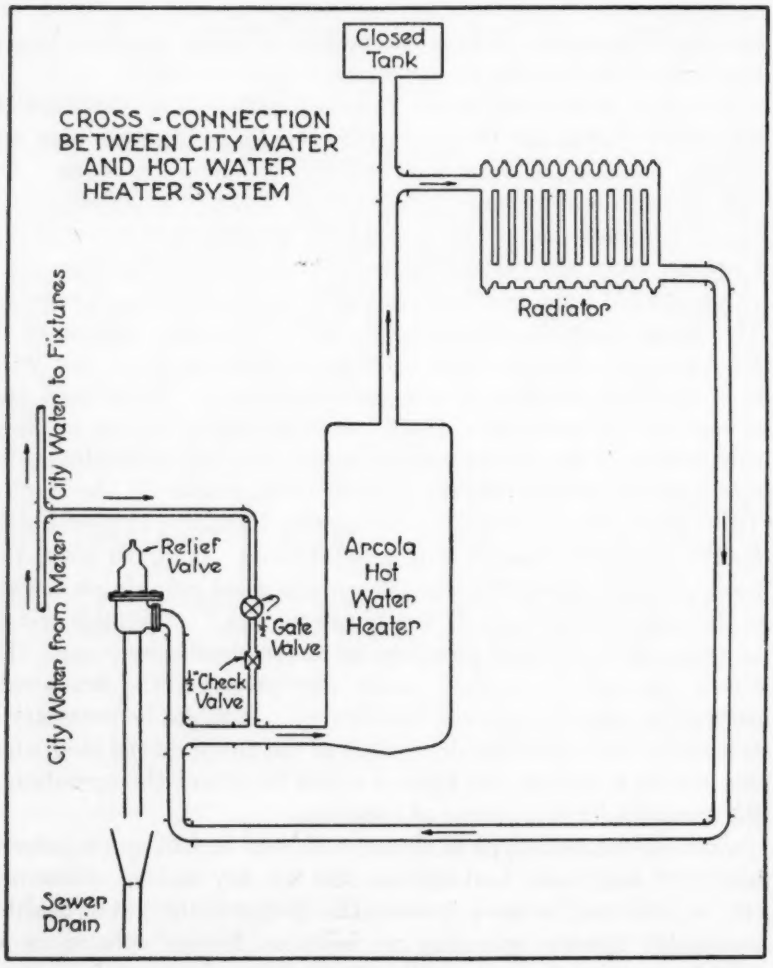

FIG. 5. CROSS-CONNECTION BETWEEN CITY WATER AND HOT WATER HEATER SYSTEM

Gate valve open, check valve defective and blow-off pressure of relief valve higher than city water pressure. Sealtite compound placed in hot water boiler was forced into city water system, causing intermittent blue discoloration of water in building.

Two of the tenants complained of blue water, but consumers in adjacent premises were not troubled in this way. An investigation revealed the fact that the gate valve to the heater in one of the stores was open and that the check valve was not operating. The investigator also learned that on account of water leakage from one of the radiators the landlord had, prior to the receipt of the complaint, purchased a patented product for sealing radiator leaks, composed chiefly of shellac, which in accordance with instructions he placed in the heater. This sealing compound was made up with a blue dye and consequently when the pressure in the hot water system was greater than in the cold water system the blue dye passed from one system to the other and appeared in the lavatories in two of the stores. It was indeed fortunate that this dye was used and that the compound contained no poisonous material. In talking with certain plumbers who have had a wide experience with conditions in Chicago the writer was informed that it was entirely probable that there were at least 50,000 similar connections in the city.

In conclusion, it is desired to state that while no cases of typhoid fever in Chicago have been directly traceable to cross-connections, the very existence of nearly 500 potentially dangerous cross-connections with other sources of supply indicates the importance of careful inspection and follow-up work by health and water departments in large cities where water supply systems of many types may be found.

The field work on cross connections in Chicago was carried out under the immediate direction of Chief Sanitary Inspector Chas. B. Ball and the inspections were made by plumbing inspector John R. Thompson and Charles Mulcahy to whom the writer is indebted for information contained in this report.

PREVENTION OF CORROSION AND "RED WATER"[1]

By John R. Baylis[2]

Any estimate of the economic loss due to corrosion of iron pipes throughout the United States would be merely a guess, but it is probably between fifty and one hundred million dollars annually. This statement is not to convey the impression that pipe repairs and replacements due to corrosion are costing the water works this amount, but when everything is taken into consideration, such as pipe repairs made by the water departments, repairs made by the consumers, loss of water through leaks caused from corrosion, damage to property from leaks, the necessity for larger pipes when it is known that the carrying capacity will be greatly reduced by the formation of iron rust, fire losses due to inadequate water pressure caused from a partial stoppage of the mains, staining of bathroom fixtures, staining of clothes being laundered, and probably other losses, the total loss is quite a large figure. That this amount may be materially reduced with a reasonable expenditure for proper treatment of the water, and that the public will be much better satisfied with non-corrosive water, are facts not fully appreciated by most water works officials.

There was a feeling in the past by the general public that water was one of nature's products and should not be changed, except to strain out the suspended matter. With this opposition it is remarkable that such progress as has been made in improving the sanitary quality of our water supplies was possible. In the attempt to give clear, pure and palatable water we have in many instances increased corrosion troubles, and occasionally to the extent where it is doubtful if the gain in sanitary safety so greatly overbalances the burdens imposed by corrosion. It is the purpose of this article to show that corrosion may be materially reduced at an actual saving to the public, and that this should be the next step in the progress of water treatment.

[1] To be presented before the Buffalo Convention, June, 1926.

[2] Principal Sanitary Chemist, Bureau of Water Supply, Baltimore, Md.

THE THEORY OF CORROSION

Before taking up the methods of treatment to prevent corrosion it is desirable briefly to explain the manner in which corrosion takes place, for unless there is a fair conception of the fundamental factors influencing corrosion rates it will be difficult to know how best to treat the water. There is a slight tendency for iron to go into solution, and if the reaction is electrochemical as suggested by Whitney[3] in 1903, the Fe ions take up a positive charge from the hydrogen ions of the solution, liberating atomic hydrogen (H). That is, Fe will replace a few of the hydrogen ions of the dissociated water giving $Fe^{++} + 2(OH^-) + 2H$. Bancroft[4] states that any chemical reaction which can be split into an anode part and a cathode part may be an electrochemical reaction. For the reaction of iron to proceed to the point of producing a ferrous hydroxide precipitate it is necessary that the atomic hydrogen be disposed of in some manner. There are two ways in which this may take place, one to combine with oxygen to form water and the other to be liberated as hydrogen (H_2) gas. When dissolved oxygen is present in alkaline solutions most of the hydrogen will combine to form water, but in acid solutions the reaction may be largely the liberation of hydrogen gas. Between these extremes the reaction may be both ways, and for most natural waters the oxidation of the hydrogen is probably in excess of the liberation of gas. It very likely is greatly in excess when a fresh iron surface is exposed, but when corrosion is taking place beneath a coating of iron rust there probably are cases when a large amount of negative ions other than the OH^- ions are present in which the prevailing reaction is the liberation of hydrogen gas, even when the water outside of the rust contains an abundance of dissolved oxygen.

Whitman and Russell[5] assume the anodic reaction in the case of acid corrosion of metals to be M (metal) $+ \oplus = M^+$, and that the cathodic reaction is either $H^+ = H + \oplus$, or $\frac{1}{4}O_2 + \frac{1}{2}H_2O = (OH)^- + \oplus$. Such a reaction accounts for the corrosion of metals below hydrogen in the electromotive series when oxidizing agents are present. If the reaction of iron is electrochemical it must react direct with the water of some electrolyte. In the absence of acids

[3] Whitney, Jour. Amer. Chem. Soc., 25, 394 (1903).
[4] Bancroft, Ind. and Eng. Chem., 17, 336 (1925).
[5] Whitman and Russell, Ind. and Eng. Chem., 17, 348 (1925).

the first product of corrosion is assumed to be the reaction with water to form ferrous hydroxide, but in their presence no reference is found as to whether the assumption is that the first product is still ferrous hydroxide, or that the Fe^{++} unites directly with the negative ions of the acid. The reaction $\frac{1}{4}O_2 + \frac{1}{2}H_2O = (OH)^- + \oplus$, given as a possible reaction, leads one to believe it is assumed that the reaction may at first be with the OH^- ions and is later replaced by other negative ions. The writer is more inclined to accept Bancroft's explanation that the formation of the salt is the anodic reaction and the liberation of hydrogen gas the cathodic reaction with acids (2). "When zinc dissolves in hydrochloric acid, the formation of zinc chloride is the anode reaction and the evolution of hydrogen gas the cathode reaction."

The reaction of iron in pure distilled water containing only dissolved oxygen is:

(1) $$\underbrace{\text{Fe(soluble metal)} + 2+\text{(positive electrons)} = \text{Fe}^{++}\text{(ionic)}}_{\text{Anode reaction}}$$

There must occur simultaneously at the cathode

(2) $$\underbrace{\text{H}^{+}\text{(ionic)} = \text{H (nascent)} + +\text{ (positive electron)}}_{\text{Cathode reaction}}$$

Fe having replaced the hydrogen in dissociated water, there is at first produced ferrous ions, but as the concentration of ferrous ions increases molecular ferrous hydroxide is produced.

(3) $$\text{Fe}^{++}\text{(ionic)} + 2(\text{OH}^-)\text{ (ionic)} = \text{Fe(OH)}_2\text{(molecular)}$$

For reactions 1, 2 and 3 to progress there remains atomic hydrogen (H) to be disposed of in some manner. Since the solution pressure of metallic iron is not sufficient to produce hydrogen gas (H_2) at ordinary water temperature apparently the only way by which corrosion can progress in pure water is by the oxidation of the atomic hydrogen.

(4) $$2\text{H(atomic)} + \tfrac{1}{2}\text{O}_2\text{(dissolved)} = \text{H}_2\text{O(water)}$$

Corrosion in natural waters containing dissolved salts, carbonic acid and dissolved oxygen is largely by the above reactions in the early stages, but soon they begin to change and much of it may be by the same manner in which acids combine with iron.

(5) $$\text{Fe}^{++}\text{(ionic)} + \text{negative ions of acid} = \text{ferrous salt}$$

In this case the hydrogen may be either oxidized or liberated as H_2 gas. It is also probable that ferrous hydroxide is still the first product and it later exchanges the OH^- ion for some other negative ion. It probably makes no difference, however, in actual practice which way the reaction takes place so long as the final product is a ferrous salt.

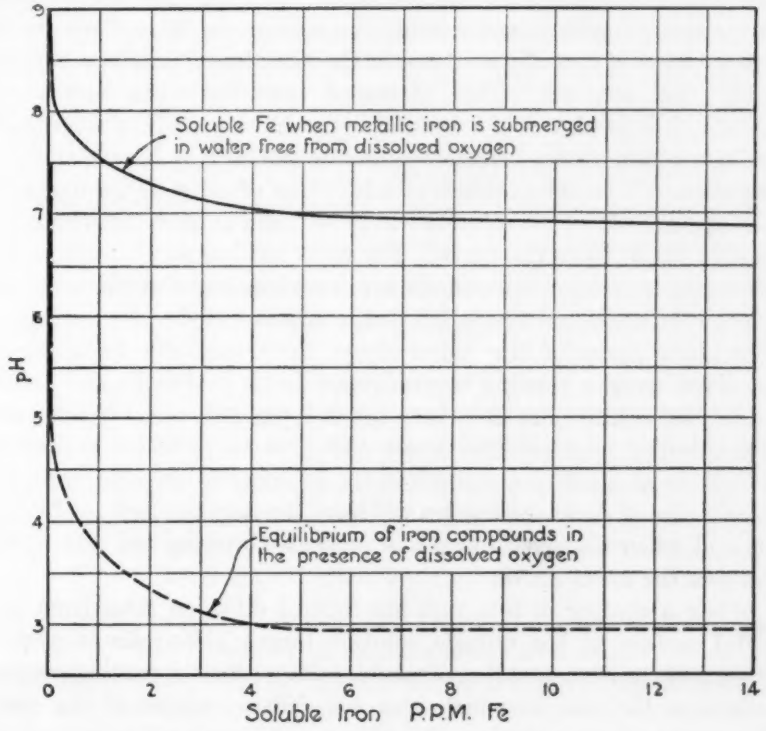

FIG. 1. RELATION OF pH TO SOLUBLE IRON

SOLUBILITY EQUILIBRIUM OF IRON SALTS

The fact that most of the corrosion in old water pipes probably is taking place in the same manner as acids combine with iron, it is desirable to know something of the equilibrium of the iron salts in contact with metallic iron. A large number of tests have been made to determine the equilibrium of soluble iron when metallic iron is in the presence of solutions having various pH values. The upper curve in figure 1 shows the amount of soluble iron which might be

expected when iron in the absence of dissolved oxygen is in contact with most natural waters having an alkalinity of about 40 and containing carbonate compounds. Points for the establishment of this curve were from quite a large number of tests and are to be published in another article. There is some variation due to the concentration of soluble compounds in the water, but the effect is of minor importance compared to that of pH. Practically no soluble iron exists at a pH of 8.0, and a saturated solution of ferrous sulfate in the presence of metallic iron and in the absence of dissolved oxygen is at a pH near 6.0. This, of course, does not mean that when metallic iron is placed in a natural water having a pH of 6.0 it will produce a saturated solution of some iron salt such as ferrous sulfate, but there will be combination or adsorption of some of the negative ions and the pH of the solution will be changed until the final equilibrium is on or near the curve. For most natural waters, where the prevailing dissolved compounds are bicarbonates, the pH will frequently be increased above 9.5 in the absence of dissolved oxygen. The lower curve of the figure shows the remarkable influence of dissolved oxygen tending to precipitate ferric hydroxide and to establish an equilibrium at a very much lower pH. A certain concentration of negative ions which will give 10 parts per million of soluble Fe at a pH of about 6.9 in the presence of metallic iron and the absence of dissolved oxygen will have the negative ions set free as an acid when dissolved oxygen is present, throwing the pH down towards the lower curve.

When a coating of iron rust has formed diffusion rates from the metal surface to the outside solution largely determine corrosion rates, and the concentration of soluble salts within the coating greatly influences the rate at which iron will diffuse outside of the rust. Should the solution within a film of iron rust have a pH of 9.0, which according to the curve allows a concentration of only 0.1 part per million of soluble iron; and that within another layer of rust have a pH of 6.5, which allows a concentration of several hundred parts per million of soluble iron; it seems evident that iron will be transferred much more rapidly to the outer surface in the latter case. There are other factors, however, which might not allow the transfer to be so rapid as solubility concentrations indicate.

TENDENCY FOR IRON TO GO INTO SOLUTION

It has been shown that iron has a certain tendency to go into solution with the formation of ions. When in solution these ions develop

what might be called a pressure in the opposite direction tending to resist more going into solution. If the solution pressure of the iron and the opposite pressure due to concentration become equal, solubility equilibrium has been reached. With some metals such as zinc, and probably aluminum, the solution pressure is so great that precipitation of the hydroxides and the liberation of hydrogen gas as bubbles takes place, even in pure water, and corrosion progresses slowly in the absence of oxygen. This will continue indefinitely or until the precipitate forms an impervious coating. In the case of

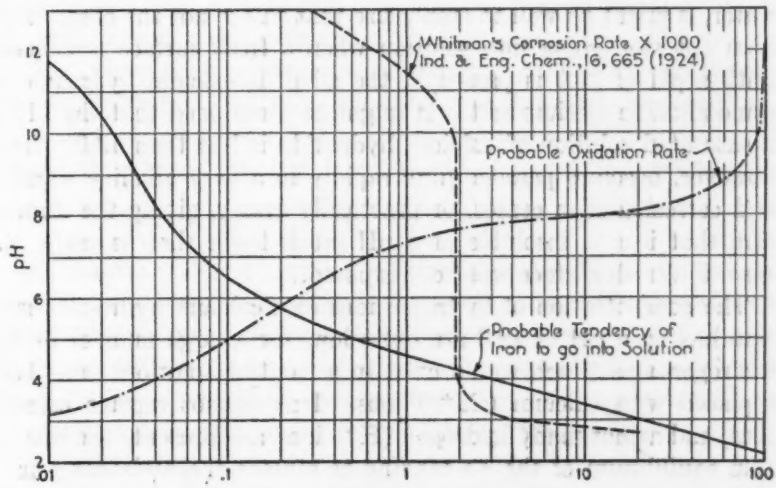

FIG. 2. EFFECT OF pH ON THE TENDENCY OF IRON TO GO INTO SOLUTION AND THE TENDENCY OF SOLUBLE IRON TO OXIDISE

Whitman's corrosion rate is penetration in inches per year per cubic centimeter of oxygen per liter.

iron, with a slightly less solution pressure, it appears that it will not corrode indefinitely in pure water in the absence of oxygen at ordinary room temperature, and probably much higher. The effect of temperature, moreover, is to increase corrosion and a point may be reached where it will continue indefinitely by the liberation of hydrogen gas. There is also a probability that the stopping of corrosion is due to the quick formation of a very thin film of iron rust which aids in reducing the solution pressure.

The factor of greatest importance in determining the tendency of iron to go into solution is the hydrogen-ion concentration of the

solution adjoining the metal surface. It has not been possible to tell if the tendency is in direct proportion to the concentration of hydrogen ions, and it may deviate at an increasing rate as the hydrogen ions increase. The curve showing the solution tendency in figure 2 is only problematical and the correct one may vary considerably from the one shown, but it is at least in the right direction. Due to so many factors tending to make the establishment of an exact curve very difficult, accurate figures are not available. Having been asked only recently by several water works chemists if corrosion does not stop when no free carbonic acid is present in the water, it might be well to emphasize that this is not the case. Iron does not stop going into solution when a fresh surface is exposed until a pH of 12.0 is passed, if the alkali is calcium hydroxide or some alkaline calcium salt. It might be mentioned that the pH of a saturated solution of calcium hydroxide is less than 13.0. Iron, however, becomes passive quite rapidly in a very alkaline solution and corrosion soon ceases, or practically ceases, giving the impression that iron is insoluble at a pH much lower than is really the case, if a fresh surface was kept exposed.

The concentration of hydrogen ions in a calcium hydroxide solution having a pH of 12.0 are quite low, for a large number of the hydrogen ions which would exist in a neutral solution have been replaced with calcium (Ca^{++}) ions. Iron cannot replace calcium ions, and as not many hydrogen (H^{+}) ions are present, the saturation equilibrium of the Fe tending to replace the hydrogen ions is not great at this pH. When the solution is completely saturated with calcium hydroxide it is likely that very few Fe ions can remain in solution, but as the calcium hydroxide is decreased the dissociated Ca^{++} ions also begin to decrease, and give room for more Fe^{++} ions to go into solution. It is not wise to make the statement that any metal above iron in the electromotive series, such as zinc, will replace and nearly prevent ferrous ions going into solution, even though the tendency is in this direction, but one so highly dissociated as calcium will almost, if not entirely. As the hydrogen ions increase in the solution the tendency is for the Fe^{++} ions to increase. There are, of course, so many factors affecting the actual rate of solution of iron that corrosion rates cannot be predicted on the basis of hydrogen-ion concentration, but the tendency for it to go into solution when the metal surface is exposed would be a function of the hydrogen-ion concentration, if there were quick displacement of the solu-

tion adjoining the metal and no tendency to form a surface coating. It may not be in a direct ratio, but no one doubts that the increase in solubility is in the direction of an increase in the hydrogen ions.

The significant fact from the standpoint of corrosion is that the solution of iron, when fresh surfaces are exposed, does not stop at a pH of 8.0 or a pH of 9.0, or at any pH to which it is practical to to treat the water of our public water supplies. That a change in pH of from 6.0 to 8.0 does not materially affect corrosion rates when fresh metal surfaces are exposed seems evident when all factors are considered. In fact several authors such as Speller[6] and Whitman, Russell and Altieri[7] find no material variations in corrosion rates under such conditions at a pH of from 5.0 to 9.5. The experiments of these authors were conducted under conditions of exposure different from what is likely to be the case in actual practice, and, while they are of great value in establishing certain facts, they give very little information as to what to expect in actual practice.

FACTORS INFLUENCING THE CORROSION OF IRON

For natural waters at ordinary temperatures with pH values between 6.0 and 9.0 the greatest factor causing corrosion to continue after a film of iron rust has formed is negative ions other than the OH^- ions and the force causing them to concentrate against the metal surface. Dissolved oxygen plays a very important part in precipitating iron rust, which is the cathodic material necessary for concentrating the negative ions, yet iron submerged in pure water containing only dissolved oxygen soon becomes very passive. It is the presence of both negative ions and dissolved oxygen, neither of which in ordinary waters produce rapid corrosion alone, that produces conditions most favorable for the rapid destruction of iron. Probably equal stress should be placed upon both. This, of course, assumes that the negative ions in the water are from neutral or nearly neutral salts. Since only a fairly narrow range of the entire pH scale is found in most natural waters the pH becomes first in importance only in the formation of protective coatings. This does not mean that the pH against the metal surface is not of great importance, but since it might be quite different from that in the surrounding solution the factors causing this difference may be of greater importance.

[6] Speller, Ind. and Eng. Chem., 17, 339 (1925).

[7] Whitman, Russell and Altieri, Ind. and Eng. Chem., 16, 665 (1924).

Any factor producing conditions tending to keep the metal surface exposed aids corrosion. In the formation of a coating of iron rust the porosity of the rust greatly affects the rate of diffusion from the metal surface to the outside. Alkaline solutions tend to form a more compact rust than slightly acid solutions. The natural tendency for iron to go into solution is so great at the pH values of our natural waters that it might be said that the life of iron pipe depends almost entirely upon the factors tending to retard corrosion. The greatest factor in this case is film formation. Anything tending to produce an impervious film aids in retarding corrosion. Suspended matter in the water frequently has an influence, especially if it is deposited in a fairly compact film against the metal surface. Ferric hydroxide is an excellent coagulant for the removal of suspended matter from water, and the precipitate so formed is apparently much more compact than if ferric hydroxide alone is precipitated. The natural tendency of iron rust is to form quite porous, except the membranes over tubercles, and the mixture of foreign matter such as silt or clay frequently materially affects the porosity. Biological growths may affect corrosion rates either way, and while much of the so-called iron bacteria are nothing more than growths of iron fibers, there are many instances where biological growths are present. Temperature is a factor influencing solution and diffusion rates, and it may have some influence upon the character of the rust formed.

It will be shown that the real problem in pipe protection is film formation. When we consider that iron is a soluble metal the importance of an impervious film for complete protection becomes apparent.

PITTING AND TUBERCULATION

In a recent article[8] the writer gave considerable space to causes for pits with overlying tubercles. The matter is of such great importance that a summary of the essential facts should be included here. The destruction of practically all water pipes is by pits, and any one who has repaired iron water pipes is no doubt impressed by the fact that holes are eaten through the metal almost as though they were drilled. Upon examination of the balance of the pipe it may be found to be perfectly sound and practically free from corrosion.

[8] Baylis, Ind. and Eng. Chem., 18, April, 1926.

That there is some unusual concentration of factors influencing the corrosion in spots is evident. In order to throw some light upon the reasons, many pits with overlying tubercles under all stages of formation have been examined. Only two constituents of the water has been found to be essential—dissolved oxygen and negative ions such as sulfates and chlorides. It, of course, is essential that the pH be not too low or too high, but it may extend somewhat beyond the ranges of most of our natural waters.

The examination of a large number of tubercles exposed to the Baltimore water, and a few from other waters, indicate that the sulfate ions are the ones most prevalent. If negative ions other than sulfates or chlorides can produce tubercles, they have not been found in large quantities in the tubercles examined. The carbonates, sulfates and chlorides constitute by far the majority of the soluble compounds found in most natural waters. Ferrous carbonate is so insoluble and the carbonate is so easily replaced by sulfate or chlorine ions that it is likely the presence of carbonates has very little influence on pitting if other ions are present. Ferrous carbonate is nearly insoluble at a pH of 8.0 or above, and when we consider that iron submerged in most natural waters having free CO_2 will finally reach an equilibrium with a pH above 8.0, it indicates that this ion alone probably will not cause typical pits with overlying tubercles. There are other essential conditions such as the production of iron rust which is cathodic to metallic iron, and the potential difference between this material and the iron must be sufficient to concentrate the ions of the salts in solution near the respective surfaces. These conditions are produced by corroding iron and no constituent of the water other than dissolved oxygen and negative ions of the proper kind are required. Other materials influence the results—some aiding and some retarding—but they are not essentials.

As a rule, all iron pipes are painted, galvanized, or have a coating of mill scale, consequently corrosion is usually localized at breaks in the coating. The early stages of corrosion, when a fresh surface of iron is exposed, are shown in figure 3. When iron salts begin to concentrate and form pits with overlying tubercles several stages of the progress are shown in figure 4. One characteristic of the iron rust so formed is that it is quite magnetic, and the building up of the rust on the metal is not by chance, but by a well applied force. Certain compounds of iron are probably more magnetic than others.

but it appears that all oxides of iron are attracted with some force. The unfortunate part is that this force, until a certain stage has been reached, tends to build up a very porous deposit and allows fairly rapid diffusion of the soluble compounds to the outside.

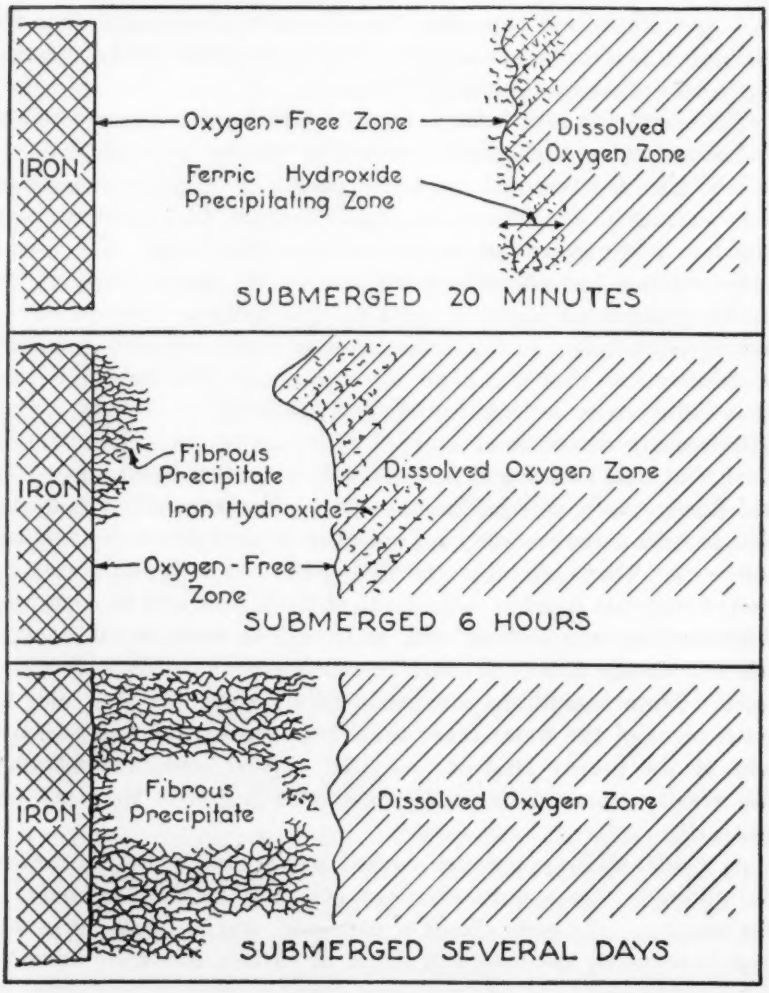

FIG. 3. FIRST STAGES OF CORROSION—THE MANNER IN WHICH THE PRECIPITATED COMPOUNDS OF IRON ADHERE TO AN IRON SURFACE

Iron is going into solution at the metal surface, combining with some negative ion present which has been drawn there by the dif-

ference in electrical potential of the metal and water. Then the nearly neutral salt diffuses through the porous deposit of iron rust to the water outside containing dissolved oxygen. Within the

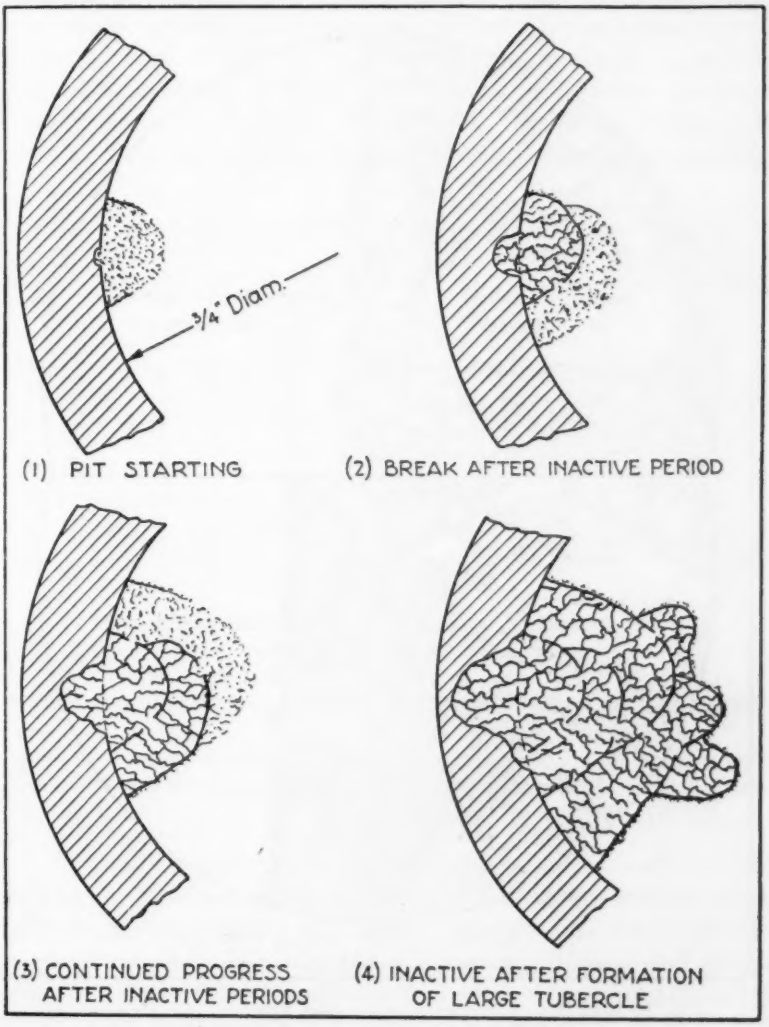
3/4" Diam.
(1) PIT STARTING
(2) BREAK AFTER INACTIVE PERIOD
(3) CONTINUED PROGRESS AFTER INACTIVE PERIODS
(4) INACTIVE AFTER FORMATION OF LARGE TUBERCLE

FIG. 4. THE FORMATION OF PITS WITH OVERLYING TUBERCLES IN A ¾-INCH PIPE

deposit of rust it is in oxygen-free water, but on reaching the dissolved oxygen zone ferric hydroxide or some hydrous oxide of iron is formed. This is much less soluble and precipitates at a much

lower pH than ferrous hydroxide. The formation of the insoluble precipitate releases negative ions formerly in combination and causes an increase in the hydrogen ions. This might not be so serious if

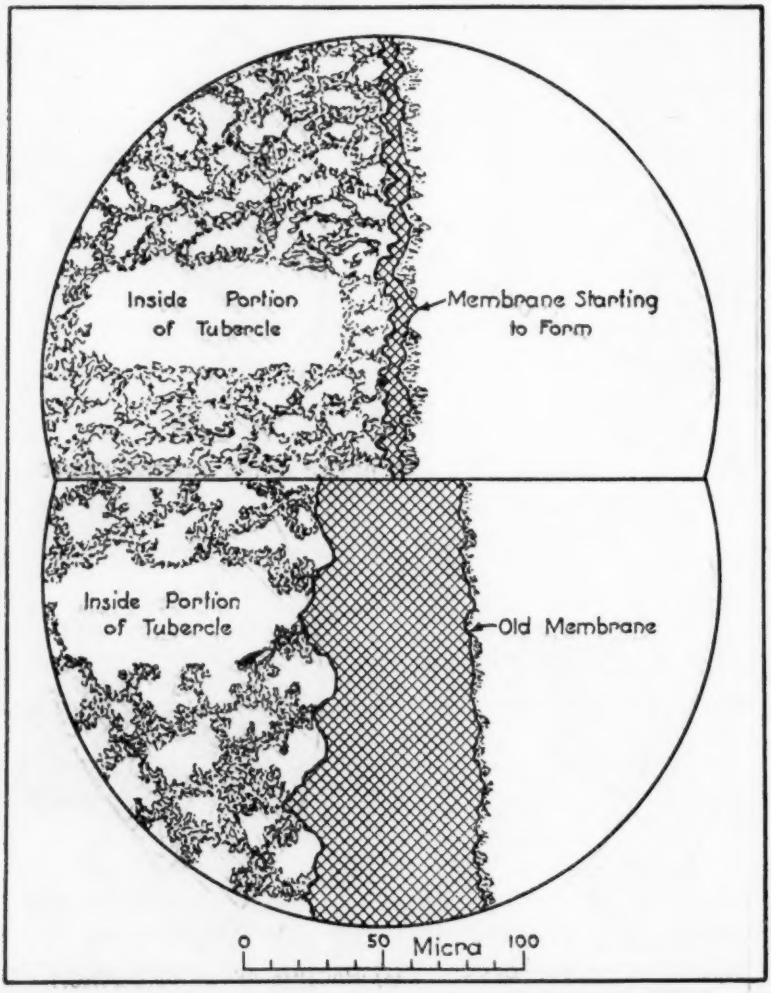

FIG. 5. MEMBRANE FORMATION AT THE SURFACE OF TUBERCLES

The membrane is a crystalline compound of iron which is quite magnetic, and eventually forms an impervious membrane over the tubercle.

the negative ions released diffused away from the surface into the water, but this is not the case. The difference in electrical potential

sends them back towards the metal surface to repeat the cycle. As the coating of rust becomes thicker a longer time is required for the salts to diffuse out, and a point is soon reached when the dissolved oxygen zone extends to the surface of the rust. The precipitation then begins to take place within, but very near the surface of the coating of rust. This forms an impervious or nearly impervious membrane, as shown in figure 5, but corrosion continues until considerable iron oxide has been precipitated. Well defined membranes only 5 micra in thickness have been observed, whereas the membrane

TABLE 1

Soluble compounds extracted from tubercles on inside of cast iron pipe

SOLUTION WITHDRAWN	DAYS STANDING	pH	SOLUBLE IRON (Fe)	Fe_2O_3	Mn	CHLORIDES (Cl)	CaO	SULFATES (SO_4)
cc.			*p.p.m.*	*grams*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*grams*
400	0.1	3.0	560	0.352	20	65	40	0.425
400	1	2.9	600	0.358	10	50	24	0.433
450	2	3.1	320	0.212	5	25	Trace	0.257
400	7	3.5	300	0.195	3	15	Trace	0.218
400	11	3.4	340	0.182	3	11		0.295
400	9	3.5	200	0.143	2	10		0.163
475	19	3.5	160	0.129	Trace	9		0.143
480	13	3.2	60	0.064		8		0.055
Total				1.635				1.989

One hundred thirty grams of wet tubercles from the inside of a 10-inch water pipe. The rust was submerged in distilled water in an open beaker. Most of the solution was withdrawn at various intervals and replaced with distilled water.

The total amount of sulfates extracted amounts to 1.53 per cent of the total weight of the wet tubercles. This means that the solution within the tubercle must have had a concentration of 4 or 5 per cent ferrous sulfate ($FeSO_4$).

over dormant tubercles are very much thicker, usually from 20 to 75 micra in thickness. During the process of membrane formation negative ions such as the sulfate and chloride ions are being concentrated between the membrane and the iron surface, and results in the formation of considerable ferrous salts. There is a possibility that the iron precipitated in this film is a certain oxide of iron essential to the concentration of negative ions, and that other oxides of iron will not cause them to concentrate. Unless suspended matter such as silt or clay has been deposited with the iron rust the inside portion of the tubercle between the membrane and the iron sur-

face becomes very porous, probably by a re-precipitation of the hydrous oxides of iron, and allows rapid diffusion of soluble salts through this portion of the tubercle. When the membrane becomes impervious the pit is dormant and the salts within the tubercle reach solubility equilibrium. The pH of the inside solution is then between about 6.4 and 6.8, depending upon the concentration of iron salts and other soluble compounds. It is possible to conceive of conditions where the pH of the inside solution of dormant tubercles is above 7.0, but for the vast majority it is believed to be within the ranges given. For corrosion to take place the pH must be below equilibrium. A number of tests indicate that the pH of active tubercles is near 6.0. However, there are conditions where this may fluctuate somewhat. The pH at least has to be slightly lower than it is at solubility equilibrium.

Much depends upon the impervious membrane formed over tubercles as to the amount of corrosion which will take place. Should the membrane be formed so toughly that it never breaks there will be complete stoppage of corrosion in the underlying pit. The character of the water, that is the pH and soluble constituents of the water, have considerable influence on the toughness of the membrane formed. Very alkaline waters may build a membrane that never breaks, whereas with fairly acid waters the breaks may be frequent. The slowness of oxidation and precipitation rates probably is one reason why slightly acid waters do not build so tough a membrane. Part of the soluble iron diffuses away from the point where corrosion is taking place into the main body of the water in the pipes, and if the water is flowing the soluble iron may be carried some distance from the point where corrosion is taking place before finally being precipitated. The precipitation is then extended more or less over the entire surface and not in spots as is the case with more alkaline waters. If a tubercle is under the process of healing a break by forming the impervious membrane at the surface where dissolved oxygen is present, and more rust is precipitated over the surface, cutting off the dissolved oxygen, membrane formation is stopped at this point. The formation of another membrane then has to start anew, probably only again to be covered with the rust before it becomes impervious.

CORROSION OF ZINC

There is every indication that zinc corrodes in the same general manner as iron, and, having a greater solution pressure, corrosion

will continue in the absence of oxygen to the point of liberating hydrogen gas bubbles. That is, zinc will continue to corrode merely by the liberation of hydrogen gas so long as the metal surface is exposed. Fortunately the oxides or hydroxides of zinc build up quite compactly on the metal surface, and if it were not due to this

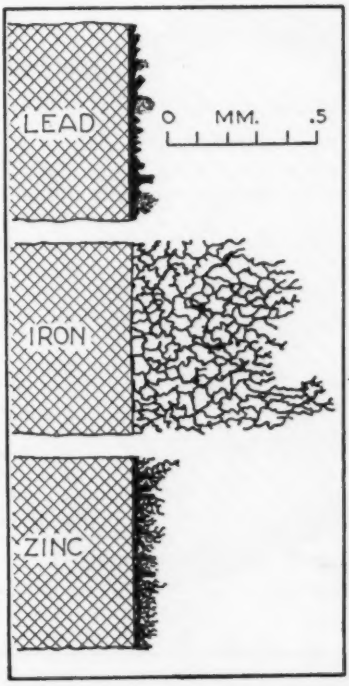

FIG. 6. CHARACTERISTIC PRECIPITATES ON METAL SURFACES AFTER BEING EXPOSED TO WATER FOR SEVERAL DAYS

Note the very compact and partially crystalline precipitates on the surfaces of lead and zinc as compared with the porous precipitate on iron. In many instances the precipitate on iron is much more compact than is shown, but such porous precipitates are frequently found. When zinc is exposed to most natural waters there is at first a precipitate of zinc oxide or hydroxide which is formed quite rapidly, but upon standing several days crystalline compounds almost completely cover the surface.

factor the life of zinc exposed to water would be short. A comparison of the precipitates of zinc, iron and lead compounds are shown in figure 6. It will be noted that the iron precipitate is frequently quite porous, whereas zinc and lead form a tough and very com-

pact precipitate. After standing for a few days the precipitate next to the metal surface becomes crystalline. With zinc it is probably a crystalline zinc hydroxide. Approximate solubility has been determined, and appears to be a curve closely following the one for

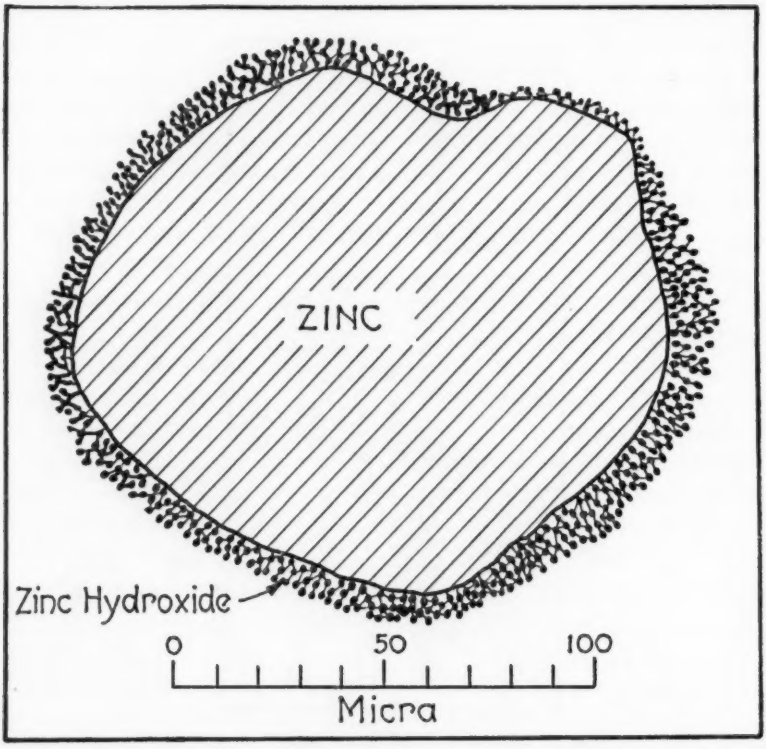

FIG. 7. METALLIC ZINC IS SLIGHTLY SOLUBLE IN WATER, POSSIBLY FIRST FORMING A HYDROXIDE, WHICH IS INSOLUBLE

The precipitation appears to be very rapid as most of the metal going into solution is precipitated on the zinc or other nearby surfaces. It forms a very tough membrane, which probably is eventually composed of both the hydroxide and carbonate. This coating offers almost complete protection to the metal in most natural waters.

iron. This is shown in figure 8. There are indications that it is just a little lower than the iron curve in the absence of oxygen. Due to the difficulty in making zinc determinations when present in small quantities the amount shown may be slightly in error. More accurate figures, however, will not shift the curve materially. A

pH of 6.5 apparently is the critical pH for zinc, and any natural water below this pH very likely will corrode zinc readily. The quickness with which zinc builds up an impervious coating in alkaline

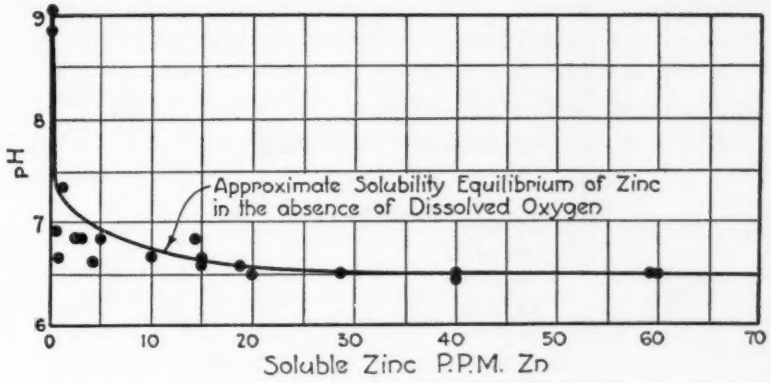

FIG. 8. RELATION OF pH TO THE SOLUBILITY OF ZINC

solutions makes the determination of true solubility equilibria more difficult than for iron.

Zinc apparently does not form pits with overlying tubercles as is

TABLE 2

Liberation of hydrogen gas by zinc metal in the absence of oxygen

TIME STANDING	TEMPERATURE	HYDROGEN GAS PER TWENTY-FOUR HOURS
days	*°C.*	*cc.*
2	20	1.6
7	20	1.4
17	19	1.1
24	21	1.5
25	20	1.0
26	38	4.5
34	38.5	3.2
35	36.5	2.0
38	36	1.9
45	37	2.0

Fifty grams of 20-mesh pure zinc metal were placed into a 500 cc. flask and filled with freshly boiled and evacuated distilled water. The flask was tightly stoppered with no air space, but contained a device projecting through the stopper for accurately measuring the liberated hydrogen gas.

the case with iron. This may be accounted for in two ways. Iron does not ordinarily produce ferrous hydroxide to the extent of pro-

TABLE 3

Solubility equilibrium of zinc in the presence of zinc sulfate

ADDED N/1 H_2SO_4	TIME STANDING	pH	SOLUBLE Zn
cc.			*p.p.m.*
2	15 minutes	4.0	
	3½ hours	6.0	
	2 days	6.5	60.0
2	2 minutes	3.7	
	2 hours	5.6	80.0
	24 hours	6.5	
	4 days	6.5	
	5 days	6.5	
	8 days	6.5	
	15 days	6.4+	50.0
	30 days	6.5−	
	39 days	6.5	
	54 days	6.5	
	70 days	6.6	18.0
	85 days	6.6+	1.0
5	5 minutes	4.8	
	20 minutes	6.2	
	18 hours	6.5	80.0
	3 days	6.5	
10	1 minute	2.8	
	5 minutes	3.0	
	10 minutes	3.8	
	15 minutes	4.6	
	20 minutes	5.8	
	25 minutes	5.9	
	30 minutes	6.0	
	40 minutes	6.2+	
	1 hour	6.4	
	1½ hours	6.4+	200.0
	2 days	6.5	175.0
	4 days	6.5	
	19 days	6.5	

Two hundred grams of pure zinc metal were placed into a 2,000 cc. flask, the flask filled with distilled water, and certain quantities of sulfuric acid added. For making the pH tests 5 cc. of the solution was removed, each time and for making the zinc tests 25 cc. was removed. The solution withdrawn was replaced with distilled water.

ducing a precipitate, consequently the soluble iron usually diffuses out to the surface of the rust, or into the main body of the water before being precipitated, and the building up of the rust which is largely by magnetic attraction is porous. Zinc will form a precipitate beneath the oxide or hydroxide already formed tending to make the deposit more compact. This tendency to compact and to form a crystalline precipitate aids in preventing a great concentration of negative ions, even though the tendency may be to concentrate.

TABLE 4

Hard spring water in contact with lead

TIME STANDING	pH	ALKALINITY	
		Phenolphthalein	Methyl orange
0 minutes	7.0	0	188
5 minutes	7.5		
10 minutes	7.8		
15 minutes	8.0		
20 minutes	8.2		
30 minutes	8.6	12	176
60 minutes	8.7	12	164
2½ hours	8.8	16	132
4 hours	9.0		
6 hours	9.5	24	104
7½ hours	9.6	24	92
24 hours	Over 9.6	32	80
32 hours	Over 9.6	32	76
2 days	Over 9.6	36	64
3 days	Over 9.6	120	160

One hundred twelve grams of commercial lead wool submerged in 300 cc. of hard spring water having a pH of 7.0, CO_2 23.8 and alkalinity 188. The water was agitated almost continuously for thirty minutes and then occasionally for the balance of the time.

There is a possibility that the difference in electrical potential of the metal and the precipitate is not great enough to concentrate ions. Zinc being bivalent only, the equilibrium of the salts in the presence of dissolved oxygen is at a much higher pH than for the iron salts.

The fact that it is better to try to protect the protective coatings on iron than to protect the iron itself, makes the problem of zinc protection of great importance. As the treatment recommended for the protection of iron will also protect zinc, the matter will be discussed more fully in another paragraph.

CORROSION OF LEAD

Even though lead is just above hydrogen in the electromotive series, it corrodes fairly rapidly when fresh surfaces are exposed, especially when CO_2 is present. Like zinc, it quickly forms an impervious coating either of oxide or carbonate of lead, probably both in many instances. The precipitate in most natural waters containing free and half-bound carbonic acid is distinctly crystalline, and the compound may be a basic carbonate of lead, $Pb_3(OH)_2(CO_3)_2$. It is not known whether there is an acid carbonate of lead or not, but the amount of lead found in solution in waters containing considerable free CO_2 indicates there may be a more acid and more

TABLE 5

Rapid reduction of CO_2 in water exposed to lead

TIME STANDING	pH	ALKALINITY		
		Phenolphthalein	Methyl orange	CO_2
0 minutes	5.8	0	52	154.0
10 minutes	6.0			
30 minutes	6.2			
1½ hours	6.4			
4 hours	6.6	0	96	21.1
24 hours	9.0			0
48 hours	9.2	8	64	0

One hundred grams of lead wool submerged in 325 cc. of the Baltimore water highly carbonated. The water was gently agitated occasionally, but not enough to release any of the CO_2. Similar treatment of a sample of the carbonated water without the lead wool showed very little loss of CO_2.

soluble compound. The coating on a lead surface builds up rapidly and it is somewhat like zinc and aluminum in that true solubility concentrations are difficult to establish. It might be said that lead is satisfactory from the standpoint of corrosion for use in all water where the pH is between 7.0 and 9.5. It also has a very long life in water of a lower pH, but the possibilities of lead poisoning should be taken into consideration.

BRASS AND COPPER PIPE

Copper and high-copper brass ("red brass") pipes are so resistant to corrosion in all natural waters that it has not been possible to form much idea of their life. Such pipe probably will be satisfactory

for almost all uses in natural waters. So long as the price is within reasonable bounds the use of such pipe may be extended with profit in some localities. It is not believed that there is enough copper available to warrant the hope that all pipes can be changed to this material. Unless there is enough to replace all pipes both large and small throughout the distribution system the water department would still be confronted with the problem of corrosion of any iron pipes which may be in the system. A general use of high-copper pipes for household laterals may be advisable in some instances, but where there is considerable corrosion of the mains such pipes may be stopped up with deposits of iron rust. In other words brass

TABLE 6

Water in contact with brass lathe turnings

APPLIED WATER		TIME STANDING	AFTER STANDING IN CONTACT WITH BRASS		
			pH	Alkalinity	
pH	Alkalinity			Phenolphthalein	Methyl orange
6.7	27	20 minutes	9.6+	7	27
6.7	27	10 minutes	9.6+	8	27
6.8	200	2 days	9.6+	7	49
6.9	120	1 day	8.6	3	44
7.9	36	4 days	8.7	3	34
6.6	23	1 day	7.6	2	26
6.6	24	3 days	8.4	1	33
6.4	26	3 days	8.7	4	33
6.5	26	4 days	8.5	2	35

About 40 grams of lathe turnings from a soft brass bar were placed into pyrex flask and about 200 cc. of water added for each test. The water was occasionally agitated.

or copper will not completely eliminate clogging of service pipes when the mains are being corroded. The writer has seen many lead pipes stopped up from such causes, and copper will not be immune under such conditions, though it may not clog so rapidly as lead pipes. Table 6 shows that brass pipe has the same tendency to remove the carbonate ions from water as iron or zinc when fresh surfaces are exposed, but a film is soon formed and there will be very little corrosion taking place.

CONCRETE AND CEMENT LINED PIPES

Someone recently suggested to the writer that, if the cast iron mains were all cement lined and all laterals were brass pipe, the problem of deterioration would be solved. It is admitted that this would greatly lengthen the life of some of our distribution systems, but a warning should be given that cement is not so durable as many believe it to be when exposed to slightly acid water, especially water having considerable sulfates. Over 90 per cent of the calcium in portland cement may be extracted when the water is corrosive to calcium carbonate. It is true the process is very slow. Nevertheless it is gradually taking place. It is now the opinion of certain chemists engaged in research work on cement that the high-calcium silicate compounds of cement gradually break down to a compound of lower calcium content when submerged and give off calcium hydroxide to the extent of forming calcium hydroxide crystals. The writer is not prepared to accept such an opinion at present, but, from a number of extraction tests conducted on various samples of concrete, it is evident that the cement compounds do give off calcium hydroxide at a gradually decreasing calcium solubility concentration until practically all the calcium is removed, if the water is corrosive to calcium carbonate. This may be illustrated by taking a sample of old concrete from within the interior of a piece of good sound concrete, pulverizing, and then submerging in a tightly stoppered flask with distilled water. If a sample containing about 10 grams of CaO is used the amount of calcium hydroxide going into solution may be approximately calcium hydroxide saturation. If most of the solution is removed and more distilled water added the concentration of calcium hydroxide will be less than in the previous solution. Repeating the extraction, practically all calcium can be removed from the concrete. Each time the amount of calcium hydroxide concentration is less than in the previous solution removed.

The danger point in concrete is frequently when part of the calcium has been removed. When it has been removed to the point where the solubility equilibrium is about one-half the saturation point of calcium hydroxide the aluminum compounds begin to go into solution. This may cause a change in the chemical composition of a large portion of the cement compounds. This is especially true when exposed to waters high in sulfates. Calcium sulfo-alumi-

nate may be formed, which is a compound that not only does not add strength to the concrete but greatly weakens it. Cement lined pipes are all right, and their use probably should be more general, but when the water is slightly acid there will be a gradual deterioration of the cement. This does not mean that cement, when a coating of sufficient thickness is used, will not add greatly to the life of cast iron pipe under such conditions. It is probably the most durable coating that can be used, but it is not a cure for all evils. Cement lined pipe, with water treated to calcium carbonate equilibrium, will have a very long life. Such pipe under this condition probably will never fail by corrosion from the inside, unless the lining becomes broken loose. The point the writer wishes to make is that, even though cement lined pipes are used, it will still be economy to treat the water to approximately calcium carbonate equilibrium.

TREATMENT OF WATER TO PREVENT CORROSION AND "RED WATER"

All efforts to find suitable pipe materials at a cheap price which are non-corrosive to slightly acid waters have failed. Should such a material now be found we are confronted with the fact that there are nearly two billion dollars worth of iron pipes in use throughout the world. No one believes that all this pipe would be replaced, even though a durable substitute should be found which costs no more than the present iron pipe. Regardless of what the future may bring forth in pipe materials, and the writer certainly does not wish to discourage research along this line; we are confronted with the problem of protecting existing pipes in the majority of our cities. In some localities the water is not corrosive and there is good protection, but in others the need is urgent. Serious corrosion is taking place in over one-half of our distribution systems. Since it has been shown that iron and zinc are slightly soluble in natural waters, the problem becomes one of protection by film formation, for it is neither practical or desirable to remove the dissolved oxygen from an entire water supply. In fact the corrosion of zinc is not dependent upon dissolved oxygen, but its presence no doubt hastens the reaction when a fresh surface is exposed. Impervious films must be formed which will prevent diffusion of soluble iron or zinc from the metal surface to the outside water. These films may be formed by precipitating the products of corrosion on the metal surface, or by producng a supersaturation of some compound in the water such as calcium carbonate which will form an impervious coating.

Films produced by the products of corrosion

It has been shown that there is no ordinary compound of iron which will exist in solution in most waters in quantities greater than 0.1 part per million of soluble Fe when the water is at calcium carbonate solubility equilibrium, or more alkaline, within the ranges of natural waters. When the water is at this point, or more alkaline,

TABLE 7

Rapid increase in pH caused by corroding iron

EXPERIMENT NUMBER	APPLIED WATER		pH AFTER STANDING THE FOLLOWING MINUTES:										STANDING 40 MINUTES	
	Alkalinity	pH	1	2	3	4	5	10	15	20	30	40	Alkalinity	Soluble iron (Fe)
														p.p.m.
1	39	7.2	7.3	7.4	7.8	8.2	8.5		8.6					0.20
2	39	6.4	6.5	6.6	6.8	6.9	7.1	7.3	7.4	7.7	7.7			
3	39	7.2	7.3	7.3	7.4	7.9	8.3	9.0	9.4				35	Trace
4	39	7.2	7.3	7.4	7.7	7.9	8.2	9.2	9.4	9.6			35	Trace
5	39	7.2	7.3	7.3+	7.7	7.9	8.2	9.0				9.6	33	Trace
6	38	7.2	7.3	7.8	8.1	8.6	8.7	9.0	9.0		9.0		35	0.10
7	38	7.2	7.3	7.7	8.2	8.6	8.8	9.0	9.1	9.2	9.3		32	Trace
8	39	7.2	7.3	7.3	7.3	7.3	7.3	7.3+	7.4	7.7	7.9	8.0	30	0.15
9	39	7.2	7.4	7.8	8.0	8.6	8.7	9.0	9.2	9.2	9.0		25	0.10

About 75 grams of lathe turnings from a black wrought iron pipe were placed into a flask, the flask nearly filled with the water to be tested, and then stoppered. The water was kept agitated by tilting the flask almost continuously for five minutes and then occasionally for the balance of the time. Experiment 1 was started with lathe turnings which has been treated with sulfuric acid and washed several times to make nearly free from the acid. After each test to no. 7, the water was all poured out and the lathe turnings allowed to stand exposed to the air while wet for several minutes. New iron lathe turnings freshly cut were used beginning with experiment 8. These experiments show that not only is all the free CO_2, but part of the half-bound is removed from the solution.

the rate of going into solution is comparatively slow and all products of corrosion where dissolved oxygen is present are quickly precipitated. It is shown by tables 7 and 8 that corroding iron usually increases the pH by removing some of the negative ions, especially the carbonates. Table 8 shows that not only is part of the half-

bound carbonic acid removed, but there is a reduction of the calcium carbonate. The corroding iron has adsorbed or combined with enough CO_2 to increase the pH above the solubility equilibrium of calcium carbonate, and has resulted in a precipitation of some of the calcium carbonate which also aids in film formation. Unfortunately, when negative ions such as the sulfates and chlorides are

TABLE 8

Reduction of CO_2 and alkalinity by corroding iron

TIME STANDING	APPLIED WATER			AFTER STANDING IN CONTACT WITH THE IRON			
	pH	Alkalinity	CO_2	pH	Alkalinity	CO_2	SOLUBLE IRON (Fe)
							p.p.m.
18 hours	6.4	34	18	7.7	36	2.0	0.2
48 hours	6.0	34	30	9.4	36	0	0.1
½ hour	6.4	35	18	7.2	35	4.5	1.0
5 days	6.5	35	15	8.6	30	0	0.1
20 hours	6.0	2	2	8.6	11	0	0.2
6 hours	7.0	72	12	9.6	52	0	Trace
24 hours	7.5	90	6	9.0	56	0	Trace
23 hours	7.2	111	12	9.4	46	0	Trace
23 hours	7.0	150	20	9.0	62	0	Trace
48 hours	7.5	180	11	9.6	40	0	Trace
48 hours	6.8	205	50	8.2	75	0	Trace
3 days	6.7	210	60	8.4	73	0	Trace
4 days	6.9	160	25	8.4	50	0	Trace
5 days	6.8	196	48	8.2	56	0	0.1
3 days	6.8	196	48	8.1	52	0	0.1
4 days	6.8	211	52	7.8	64	1.0	0.3
5 days	6.8	200	50	8.0	55	0	
2 days	6.8	188	45	7.6	72	3.2	0.3
3 days	6.9	188	40	7.8	58	0.8	0.1

About 50 grams of iron lathe turnings from a black wrought iron pipe were placed into a 250 cc. glass tube and the tube loosely stoppered. The reduction in alkalinity is due to the reduction of free and half-bound CO_2 producing a pH above the calcium carbonate solubility equilibrium curve.

present they concentrate in spots and pits and overlying tubercles are formed before the surface film becomes impervious. When water is at the solubility equilibrium of calcium carbonate, which is shown in figure 9, fairly tough membranes are formed over pits. These membranes occasionally break and allow corrosion to continue until another one is formed, but the breaks are not nearly so numerous in alkaline waters as they are in slightly acid waters.

Zinc has a greater tendency than iron to form impervious films when the pH is above 6.5, and when it is near the calcium carbonate curve the life of the galvanizing is greatly lengthened. If a fresh zinc metal surface is exposed to fairly alkaline water the first product of corrosion appears to be a gelatinous hydroxide of zinc, but on

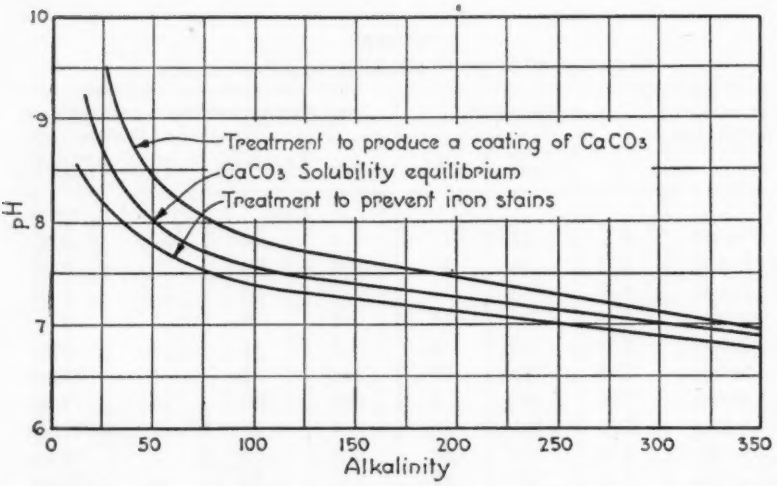

FIG. 9. RELATION OF pH AND ALKALINITY TO THE PROPER TREATMENT OF WATER TO PREVENT CORROSION

The calcium carbonate solubility curve shown is based upon calcium carbonate in distilled water at 22°C. It is approximately correct for natural waters low in soluble salts, but should be checked when used on waters containing considerable dissolved compounds. If it is desired only to prevent staining of toilet fixtures, etc., and to have an occasional occurrence of "red water," the water may be treated to the lower curve. When it is desired to form a protective coating of calcium carbonate, lime should be added until the pH falls on the upper curve, or slightly higher. Calcium carbonate will then be precipitated only on solid surfaces. Should lime be added until the pH is considerably above the curve there is danger of forming a calcium carbonate precipitate throughout the solution. After a coating has been formed the water may be treated only to the calcium carbonate curve, or slightly higher.

standing a few days a crystalline precipitate builds up next to the metal surface. This was at first thought to be a carbonate of zinc, or some basic compound, but what appears to be the same type of crystal has been formed when zinc metal is submerged in distilled water made slightly acid with sulfuric acid. It is probably a crys-

talline zinc hydroxide. These crystals are not stable below a pH of about 6.4, or probably slightly lower, and this may be the main reason why galvanized iron pipes do not last very long when the pH of the water is below this point.

Iron pipe without a protective coating of zinc or some durable paint should not be exposed to any of our natural waters. It is possible to form impervious films which will eventually stop corrosion, but not until considerable tuberculation has taken place and the pipes reduced in carrying capacity. It is far better to protect the zinc on galvanized pipes and the paint or cement coating on cast iron pipes than to try to protect iron surfaces. In case it is not desired to produce a coating of calcium carbonate on the pipe surfaces, *all public water supplies should at least be treated to where very little soluble iron will exist in the water in the absence of dissolved oxygen.* When so treated there is fairly rapid healing of the breaks in tubercles and the tubercles do not grow so large as they do in more acid waters. Almost any alkali probably is suitable for this treatment, but it is better from the standpoint of corrosion to use caustic alkalies and not carbonates such as sodium carbonate. Any compound adding negative ions other than the OH^- ions to the water has a tendency to increase corrosion over what it would be if none were added. This is assuming other conditions such as pH and alkalinity are equal. Sodium carbonate is now used in some water treatment plants to increase the pH, and it may be very effective in preventing stains and may also reduce corrosion, but the compound itself does not form a precipitate and aid in film formation as is the case with calcium carbonate. It has the advantage, however, of not adding soap hardness to the water.

If it is desirable merely to prevent staining, and to reduce "red water" troubles to an occasional occurrence, the water should be adjusted to the lower curve in figure 9 with almost any suitable alkali. It should be understood that the treatment to this curve does not entirely stop corrosion, but will reduce it to where it is not serious if the pipes have good protective coatings applied by the manufacturer. In fact such a treatment will offer almost complete protection to galvanized iron, cement lines and lead pipes. There is a question as to whether treatment should be stopped at this point, or be continued to the point of producing a calcium carbonate coating, which almost completely stops corrosion. The writer is inclined to favor complete protection.

Treatment to produce a coating of calcium carbonate

Treatment of water with lime appears to be the cheapest and most effective means of protecting iron pipes on the inside. The alkaline sodium compounds are so soluble that their chief aid in preventing corrosion is to produce conditions more suitable for the precipitating or depositing of other less soluble compounds occurring in the water. The addition of sodium hydroxide or sodium carbonate to waters containing considerable calcium bicarbonate may produce a supersaturation of calcium carbonate and cause a precipitate. The amount of calcium carbonate which will be held in solution depends

TABLE 9

Loss of alkalinity by passing alkaline water through 50 feet of ¼-inch black iron pipe which has been in service eight months

BEFORE PASSING PIPE			RATE OF FLOW PER MINUTE	AFTER PASSING PIPE		
pH	Alkalinity			pH	Alkalinity	
	Phenolphthalein	Methyl orange			Phenolphthalein	Methyl orange
			cc.			
9.5	26	51	28	9.3	20	45
9.5	28	52	22	9.3	16	44
9.4	22	50	30	9.3	16	46
9.4	26	51	33	9.3	16	45
9.5	28	52	18	9.3	20	43
9.4	29	51	12	9.2	17	42
9.6	24	50	23	9.3	16	44
9.4	26	50	20	9.1	16	43

Tests were made at various intervals during a period of eight days.

upon the alkalinity, hydrogen-ion (pH) concentration, and to a slight extent upon the amount of neutral salts present. No certain alkalinity or pH can be set as that desired for all waters. The calcium carbonate equilibrium curve in figure 9 shows that it is only by a knowledge of both pH and alkalinity that the saturation point of calcium carbonate may be estimated. The saturation or solubility equilibrium point is where the water will neither dissolve nor precipitate calcium carbonate. Water containing a large amount of certain neutral salts such as the sulfates and chlorides will give curves slightly different from the one shown. In such cases it is desirable to establish a curve for the particular water. This may be done by adding a large excess of calcium carbonate to the water and

sealing in a non-corrosive glass container for about one week. The sample should be thoroughly agitated several times daily. It

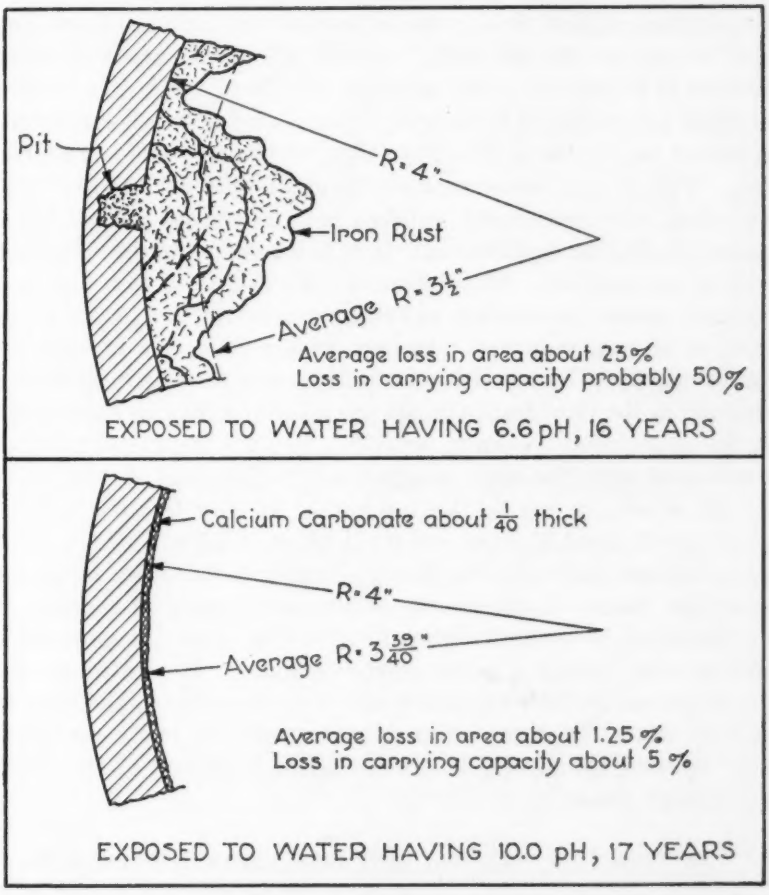
Pit
R. 4"
Iron Rust
Average R. 3½"
Average loss in area about 23%
Loss in carrying capacity probably 50%
EXPOSED TO WATER HAVING 6.6 pH, 16 YEARS
Calcium Carbonate about 1/40 thick
R. 4"
Average R. 3 39/40"
Average loss in area about 1.25%
Loss in carrying capacity about 5%
EXPOSED TO WATER HAVING 10.0 pH, 17 YEARS

FIG. 10. SECTIONS OF CAST IRON PIPE EXPOSED TO CORROSIVE AND TO NON-CORROSIVE WATER

The drawings show typical conditions found in two fairly large cities having different characters of water. A slight adjustment of the pH of the water in the lower sketch will stop the precipitation of any additional calcium carbonate.

is impossible to apply lime intelligently to water without a knowledge of the hydrogen-ion concentration, yet it is a factor many try to ignore.

In the formation of a calcium carbonate coating it need not be

thick enough to materially reduce the carrying capacity of the pipes. The writer has seen coatings not over $\frac{1}{64}$-inch in thickness which offered almost complete protection. Almost any water softened by the addition of lime, or any water treated with sulfate of iron and lime to remove the suspended matter will form such a coating. When it is for softening the tendency will be to build up a coating too thick unless the pH is reduced. There have been a few attempts to correct this by the addition of CO_2 to the water just before filtration. This is good practice, even though additional negative ions are added, but care should be taken not to decrease the pH below calcium carbonate equilibrium. It is much better to use CO_2 than sulfates or chlorides. Water treated with sulfate of iron and lime probably comes the nearest to being adjusted to the proper treatment to prevent corrosion. In fact, with a little care in correctly controlling the pH, and with the small amount of calcium carbonate removed in the filter beds, the pH and alkalinity may be kept almost on the upper curve shown in figure 9. In some instances sulfate of iron is used when the water is softened with lime, and at such places the pH is usually just a little too high. At New Orleans, with an alkalinity of about 35 to 40 and a pH between 9.5 and 10.0, a coating of calcium carbonate less than $\frac{1}{32}$-inch in thickness has formed in seventeen years. Compare the reduction in carrying capacity in this situation as shown in figure 10 with that of conditions found in another city having a fairly corrosive water. It is evident that the treatment at New Orleans is the more desirable of the two, especially when the New Orleans coating may be easily prevented from building up any thicker by a slight adjustment of the pH of the filtered water.

THE EFFECT OF CLEANING CAST IRON MAINS IN CORROSION

Where there is serious tuberculation of cast iron mains their carrying capacity is frequently reduced over 50 per cent, or to a point where an adequate supply of water cannot be furnished in case of a fire. In such instances it is necessary either to clean the existing mains, or to lay new ones. The customary procedure in cleaning water pipes is to run some kind of a device through them which will knock loose the tubercles. When done efficiently the original carrying capacity of the mains may be nearly restored immediately after cleaning. After such cleaning will the rate of tubercle formation and clogging be faster than originally? Every evi-

dence points to the fact that it will be. The writer has been informed by several water works superintendents who have had part of their mains cleaned, where the water is fairly corrosive, that it is

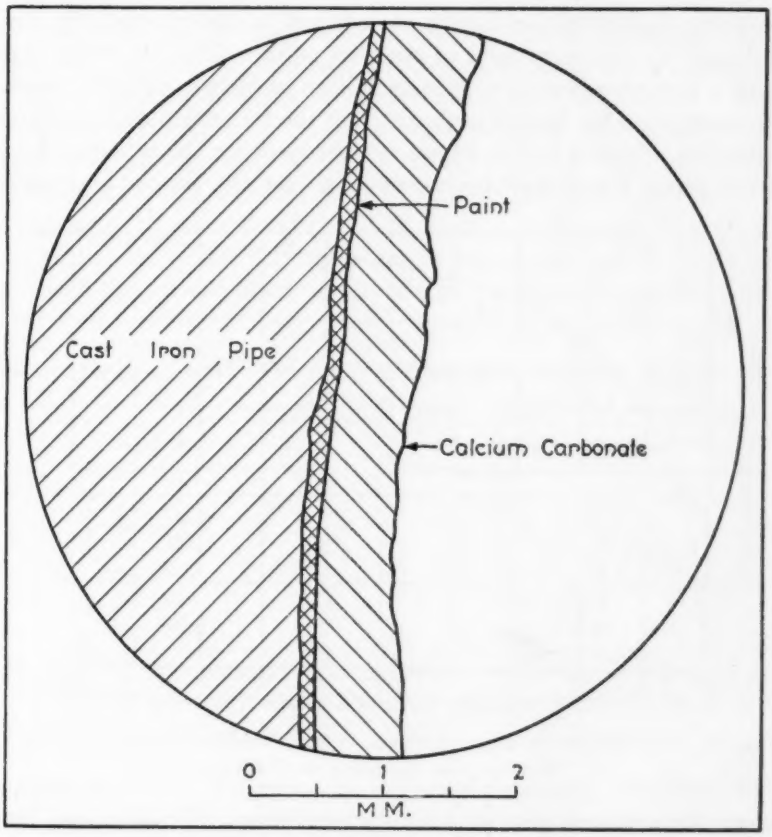

FIG. 11. CAMERA LUCIDA DRAWING OF CALCIUM CARBONATE PROTECTIVE COATING ON THE INSIDE OF PIPES AT NEW ORLEANS, LA.

Water after treatment at the filtration plant has a slight tendency to precipitate calcium carbonate. This offers almost complete protection to the pipes. The average thickness of the coating after about seventeen years of such treatment is about 0.6 mm.

only a matter of two or three years until they are again clogged. All indications point to the fact that cleaning cast iron mains of tubercles hastens their final destruction by corrosion.

The corrosion of cast iron does not dissolve all materials mixed

with the iron. Consequently when removing a tubercle there is no indication of where the pit is located unless the surface is scraped with a chisel or some other sharp tool. Even though practically all iron is dissolved from the pit the other constitutents of the cast iron hold together firmly enough not to be removed by any ordinary method now used in cleaning pipes. The pit being filled with a ferrous salt such as ferrous sulfate or ferrous chloride, conditions are ideal for immediately starting the formation of fairly large tubercles. This is not to advise against cleaning the tubercles from water pipes, for it may be necessary to get the desired amount of

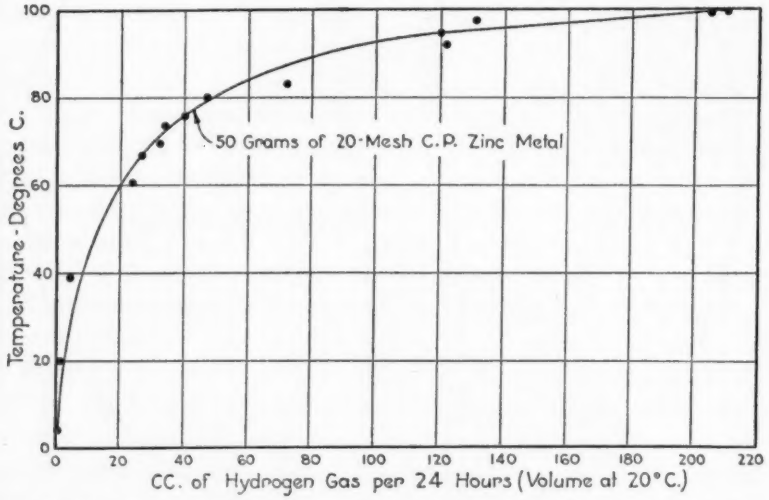

FIG. 12. THE EFFECT OF TEMPERATURE ON THE INITIAL CORROSION RATE OF ZINC IN THE ABSENCE OF OXYGEN

water through, but the relief is only temporary. If there were some treatment whereby an impervious coating could be quickly deposited on the pipe surface it might be of great aid in retarding corrosion and clogging. The writer knows of no treatment to recommend in such instances, but it is possible that sodium silicate may be used to advantage. Fairly large tubercles will form over pits before a coating of calcium carbonate can be deposited, for it takes several months to form a coating with water as alkaline as it is practical to use.

STUDIES ON THE EFFECT OF TEMPERATURE NOT COMPLETE

Experimental work on the effect of temperature on corrosion is under way, but has not progressed to the point where positive results

can be stated. A few hot water lines have been examined, and a few experiments made with temperatures between 20° and 100°C. The tests so far show nothing contrary to recent literature, in that an increase in temperature increases corrosion rates. Increasing the temperature probably aids in several ways. Diffusion rates are increased, thereby enabling soluble compounds aiding corrosion to be brought against the metal surface much more rapidly. The thickness of the oriented layer of water against solid surfaces appears to be much less for hot water than for cold. This enables the soluble salts within the film of rust to diffuse through more freely.

Increasing the temperature of 50 grams of 20-mesh laboratory zinc in distilled water and in Baltimore tap water from 20° to 55°C. increased the rate of liberating hydrogen gas about 2 times, and in-

TABLE 10

The effect of temperature on the rate of hydrogen gas liberation by the corrosion of zinc

TEMPERATURE	HYDROGEN GAS MEASURED AT 20°C.
°C.	cc.
20	1.3
37	2.2
53	3.6
95	120.0
100	175.0

Fifty grams of 20-mesh C.P. zinc metal were placed into a 300-cc. pyrex flask and Baltimore tap water added. The water had alkalinity 50, pH 8.5 and CO_2 0.0.

creasing to 100°C. the rate was increased to nearly 100 times the rate at 20°. This is shown in figure 12. In these tests the hydrogen gas was cooled to 20° before measuring. With the device used for collecting and measuring the hydrogen gas very accurate measurements can be made.

There also appears to be another factor aiding the corrosion of zinc by hot water. The surface film of zinc hydroxide is not built tough enough to protect the zinc metal as is the case when the temperature is lower. This, and the rapid corrosion rate of zinc in hot water, is probably why galvanizing on the inside of hot water lines does not last very long.

IT IS ECONOMY TO TREAT WATER TO PREVENT CORROSION

The City of Baltimore has about $25,000,000 worth of cast iron mains, and about $4,000,000 worth of laterals leading from the mains to the curb stop. In addition to this there are about 165,000 homes and business houses with water connections. The value of the iron pipes in these houses is probably $8,000,000. The pH of the Baltimore water after coagulation with alum is between 6.0 and 6.8. This is about the same pH as the water which is being supplied a number of cities without any treatment to prevent corrosion. A fair estimate of the average useful life of cast iron pipes exposed to such an acid water is about seventy-five years, and for galvanized iron pipe not over twenty years. The twenty years estimated life of service pipes is the average of both cold and hot water lines. The hot water lines, of course, do not last as long as the cold water lines.

Treatment of the water to the point of coating the pipes with a thin film of calcium carbonate should more than double the useful life of pipes, if all corrosion were from the inside. It is safe to say that with such a treatment the life of cast iron pipe will be increased at least fifty years and the service pipes at least ten years, even after taking into consideration corrosion from the outside. $25,000,000 worth of cast iron pipe at an estimated useful life of seventy-five years will have an annual depreciation of about $333,000 and $4,000,000 worth of household lateral owned by the city and about $8,000,000 worth of iron pipes privately owned, with a life of twenty years will have an annual depreciation of about $600,000. With the water treated to prevent corrosion, which will give a useful life of one hundred and twenty-five years for cast iron pipes and thirty years for the smaller pipes, the annual depreciation is about $200,000 and $400,000 respectively. This gives a grand total annual depreciation of $933,000 for the acid water and $600,000 for the properly treated water, or a saving of $333,000.

The cost of treatment to reduce corrosion in Baltimore has averaged about 33 cents per million gallons for the past three years, or a total of about $12,000 annually. The increase in hardness, which averages about 10 to 12 parts per million, probably adds from $15,000 to $20,000 annually for additional soap, etc. On the other hand there is a saving by preventing stains on bathroom fixtures and clothes being laundered, and, in addition, the value of

satisfied consumers. This should at least partially overbalance the added cost. If the Baltimore water were treated to the point of almost entirely preventing corrosion the cost would be about 20 per cent higher than the figures given. If we assume that no value should be placed on satisfied consumers, the total annual saving would still be nearly $300,000. With the present treatment where corrosion is not entirely stopped the saving is somewhat less, but at least $200,000.

These figures may not apply in the same proportion in other cities having corrosive water, but there will at least be a great saving. There is also the possibility that the life of iron pipes are not correctly estimated, but whatever be the life in slightly acid waters, it will be greatly extended by properly treating the water. When some of the other losses caused by corrosion which are numerated in the first paragraph of the article are taken into consideration the saving will be even greater than the figures above given.

THE WATER SUPPLY OF THE CHICAGO AND NORTH WESTERN RAILWAY[1]

By R. E. Coughlan[2]

On the Chicago and North Western Railway, the importance of suitable water for locomotive boiler use has been recognized for many years. This railroad is one of the pioneers in the soft water field.

Our road, comprising in all 10,215 miles of tracks, extends from Lake Michigan to the Rocky Mountains, traversing in all nine states.

Our problem has been to secure the best water available at all of our water stations and when this water is unsuitable for economical boiler operation, to render it so by means of chemical treatment, keeping in mind at all times the fact that the primary function of a boiler is to furnish power for the successful operation of machinery.

The water available for boiler use varies from the soft water of Northern Wisconsin, some of which contains as little as two grains of temporary hardness, to the very hard water of Minnesota and Dakota, some of which contains as high as eighty grains of temporary and permanent hardness per gallon. In certain parts of Wyoming and Dakota, the available water is known as "alkali." This water, while containing very little hardness, has in solution an excessive amount of the alkali sulphates and carbonates which have a tendency to cause boilers using it to prime. This is a serious menace to successful boiler operation. A special treatment is required when using this kind of water.

Throughout Northern Wisconsin and Michigan, the water is generally soft, so that very little treatment is required to keep the boilers in excellent condition. Such treatment as is used is applied directly to the locomotive tanks. This treatment consists of sodium carbonate commonly known as "soda ash."

The first definite step in the improvement of the quality of the water before supplying it to locomotive boilers on our road was made

[1] Presented before the Illinois Section meeting, March 25, 1926.

[2] Supervisor of Water Supply, Chicago and North Western Railway, Chicago, Ill.

early in 1903 on our main western division in Iowa, known as the "Iowa Division." This division extends from Council Bluffs to Clinton, Iowa, a distance of 348 miles, and over it is hauled a large percentage of grain and live stock on the way to Chicago and Eastern markets. Trains of this nature must be moved without delay as a loss of several hours in reaching the market may mean a direct financial loss to the carrier. Prior to 1903, it was the practice, when the traffic was heavy, to have reserve locomotives in readiness along the division to relieve locomotives liable to fail because of leaking or other boiler troubles.

The initial step in water improvement consisted of the construction of 16 lime and soda ash plants throughout this district. The entire installation was completed in 1904.

With these softening plants in operation, the locomotive boilers showed an improvement that was almost unbelievable. The resulting increased life of boilers, lower maintenance cost, fuel saving, etc., soon returned the initial cost of these plants. The reserve locomotives became a thing of the past and today our passenger locomotives operate over this entire district each day, being held in the terminals only long enough for the necessary running repairs. A boiler failure because of leaking is unknown.

These original plants were of the intermittent type and with the exception of the first one were all constructed by our own forces. As funds became available this program of construction was extended until there were 30 softening plants in operation at various water stations in Illinois, Iowa, Minnesota and Dakota.

After the World War, our interrupted program was again taken up. In 1922 we installed two of the modern plants of the continuous type.

In 1923–4, five, and in 1925, six were installed. The program of improvements for this year includes eleven more.

Our present daily consumption of softened water is approximately 4,000,000 gallons. From this volume of water, we remove over seven tons of scale forming solids per day. Some idea of the financial value of removing this amount of scale may be obtained if we refer to an investigation made by a committee of 10 engineers of the American Railway Engineering Association in 1913. They reported that the use of boiler water containing at least 13 grains of scale forming matter per gallon, caused a loss due to excessive fuel consumed, excess boiler

repairs and time out of service that amounted to 7 cents per pound of scale contained in the water.

In 1923 another committee of the same association, consisting of 27 engineers, made another investigation on this subject. The following quotation is taken from their report in Vol. 25, No. 261, November 1923.

> Your committee is of the opinion that the money value of the damage done to railroad revenue by the use of waters only moderately unsuitable has been much under-estimated, and that the custom common to all railroads of keeping a locomotive in a bad water district for three or four months, then transferring it for the balance of the year to a good water district, and distributing the repair charges has much befogged the issue.
>
> We have checked the measurements of your Water Committee of 1913, who reported in Vol. 15 of the Proceedings, that a boiler using water of 13 grains per gallon hardness, suffered damage in fuel and boiler repairs and time lost to the amount of 7 cents per pound of scale, and we consider them quite accurate on condition that the amount is raised to 13 cents per pound of scale to correspond to the prices of today.

In the operation of these water softening plants, we endeavor to reduce the original hardness to 3 to 5 grains per gallon. Zero hardness applied to some of the natural waters which we soften would result in a water which we call "light." This means that the water contains in solution so much sodium sulphate or similar substances that, when used in a boiler, it causes priming or foaming and the steam instead of being dry contains considerable moisture which is a detriment to economical boiler operation. We are obliged to use this class of water in parts of Wyoming and Dakota and in order to overcome this tendency, a special treatment known as anti-foaming boiler compound is used. The cost of this treatment is quite high and while we use it on all locomotive districts where necessary, we prefer to hold our treatment for scale to a point where the boilers are kept in good condition without causing any light water.

Our locomotive engineers are carefully coached and encouraged to reduce the concentration in the boiler while in operation by means of short openings of the blow off cocks at frequent intervals.

In addition to the complete lime and soda ash plants, we have 40 soda ash plants. These are small auxiliary pumps or similar devices which force dissolved soda ash into the storage tanks in direct proportion to the amount of water pumped. This is a satisfactory method of eliminating the permanent hardness of waters at stations

where we have, as yet, not installed complete lime and soda ash plants.

We have always used some boiler compound at points where we have no softening facilities. These compounds are made by our own forces under supervision of our chemical laboratory. During the past five years, we have been developing ways and means for securing the best results when this kind of treatment is used. We have devised several feeding arrangements and each terminal where this treatment is used is furnished with a test outfit. The foreman in charge makes daily tests of samples of water taken from the locomotive boilers. These test results are sent into the laboratory daily and are checked against analyses made at regular intervals. By this means, we are able to control the treatment, and have secured very satisfactory results.

In checking the records of boiler performance for the past 15 years, we find that in 1911, when our road was partially equipped with softeners or other treatment, we had 787 locomotive failures due to leaking flues. The average for the year was 58,633 miles per flue failure. In 1925, we had 27 locomotive failures from this cause, and the average was 1,770,119 miles per failure. During the year 1925, our Division in Iowa, equipped with softeners built in 1903, had an average of 7,125,421 miles per flue failure.

Each year we are striving to do better. Our management is keenly alive to the benefits derived from operation of locomotives which are furnished water free from impurities. We have the cooperation of not only the Motive Power Department, which is vitally interested, but also the Engineering Department, Traffic Department, and all our general officers, who realize the direct financial return, when boilers are supplied with suitable water.

That the general public is becoming interested in this subject is shown by an article in the Chicago Daily Tribune, March 23, 1926, entitled "Railroads Show Steady Increase in Efficiency" from which I quote the following:

> Some of the means by which railroads are getting more work out of their equipment are little known to the layman. For instance, did you know that the Iron Horse is becoming ever more a bottle nursed animal? Nowadays they have to treat his boiler water as carefully as a mother modifies her baby's milk.
>
> A change from raw, muddy water—as is—to soft and clean water, has been known to save $4,000 per year per locomotive in repairs and increased fuel efficiency. It isn't the water after all which is dangerous, it's what's in it.

DISCUSSION

K. HOLADAY: In regard to the control of your treatment plants how much supervision do they have by a chemist?

R. E. COUGHLAN: The operation of the softening plants is under the jurisdiction of the Engineering Department. The pumpers in charge make daily reports to the Engineer of Tests. Samples of treated water are sent in twice a week for analysis. The raw water is analyzed as often as required to keep in touch with the varying character of the water. Where the pumpers have test apparatus, daily tests are made and reported. The operation is checked as often as possible by a chemist. The water supply foreman is responsible for the satisfactory operation of the plant.

L. R. HOWSON: Does the control of the plants on the Illinois Central differ?

C. R. KNOWLES: Not materially. The operator makes daily tests. A chemist visits the plant once or twice a week or sometimes not for two weeks.

L. R. HOWSON: Who has the responsibility of changing treatment?

C. R. KNOWLES: The operator. At Galena, for example, there may be a shower in the hills and in thirty minutes the character of the water would be changed. It is necessary that the operator be responsible for change in treatment.

L. R. HOWSON: In some municipal plants treatment of water may be shown to be economical, if it will allow saving one half bar of soap a week for each domestic consumer. Another saving is in heating coils. From an investigation in one town the average cost of heating coils with untreated water was estimated at $12.00 a year.

C. R. KNOWLES: Our only trouble is to trim down the actual figures on the saving from use of treated water so that they will be readily believed and be acceptable.

PAUL HANSEN: How much salts are present before you classify water as light?

R. E. COUGHLAN: We have found it necessary to use anti-foam compound when the water in the boilers exceeds a concentration of 400 grains per gallon of alkaline salts. With anti-foam compound we can carry about four times this concentration. By means of the blow off cocks our enginemen reduce the concentration where the anti-foam compound is not used below 100 grains per gallon. Our treated water usually has an alkali content of less than 75 grains per gallon. We have a general working schedule that anti-foam compound will not be used unless our alkaline salt content shows over this amount. We also try to carry all of our treated water to 1 grain excess of sodium carbonate.

A. M. BUSWELL: Do you always use an excess of soda?

R. E. COUGHLAN: Yes, the alkalinity of the treated water is always slightly greater than the hardness.

PAUL HANSEN: What is the basis of your anti-foaming compound?

R. E. COUGHLAN: Castor oil.

A. E. GORMAN: Is the basis of the successful use of castor oil physical?

R. E. COUGHLAN: We consider the reaction to be a physical one in that it reduces the surface tension.

M. M. SYMONS: How much oil is used?

R. E. COUGHLAN: We use a mixture containing approximately 15 per cent of castor oil. One pint of this mixture is sufficient to hold down 7500 gallons of water.

QUESTION: Is the treated water used for domestic consumption?

R. E. COUGHLAN: If the raw water supply is safe the treatment will not to my knowledge render the water unfit for domestic use. Theo-

retically it is a very dilute solution of Glauber salts, which as you know is a standard remedy in veterinarian practice. At one point on our lines we turned the treated water into the city mains in an emergency due to the failure of the city supply. This was continued for a period of some weeks and when the city again turned the old water into the mains the consumers complained of the taste, as they had grown to like the taste of the treated water. No ill effects from the use of treated water have ever come to my attention on our road. We do not use it, however, on any of our coaches or in any place where it is liable to cause any comment whatsoever. We do not consider it at all injurious, but we do not want to cause any apprehension in regard to the water furnished the traveling public.

C. R. KNOWLES: I drink the treated water in preference and many of our employees do, but we do not furnish it to the public on our trains.

THE COLI-AEROGENES GROUP IN SOIL

By Stewart A. Koser[1]

Since the introduction of simple methods for separating the coli-aerogenes group of bacteria into several sections, the so-called fecal and non-fecal types, there has been considerable discussion regarding the practical application of these methods in the sanitary examination of water. Some workers claim that they are useful in arriving at a correct judgment of the sanitary quality of water, while others state that they are of no value.

It is clear that to evaluate these tests accurately we should have as extensive knowledge as possible regarding the types of colon group organisms found both in the feces of man and animals and in various soils, for it is evident that most of the coli-aerogenes types which make their way into water supplies are derived ultimately from one or another of these sources. It now appears clearly established that the Bacterium coli section comprises about 95 per cent of the colon-like organisms found in the intestines of man and the higher animals, while in contrast to this Bacterium aerogenes and its allies predominate in soil. However, the latter are by no means the only colon-group representatives to be found in soil, for organisms resembling the intestinal coli type have also been encountered, though usually in smaller numbers (1).

In this connection it should be recognized that from the sanitary point of view different soils may vary widely, since some are obviously exposed to fecal contamination to a greater degree than others. It seemed desirable to determine whether the proportion of the various coli-aerogenes types in soil would vary in harmony with the degree of fecal contamination to which different localities may be exposed. Such a comparison would serve to throw some light upon the value of the differential tests as criteria of pollution, not only as applied to soils, but indirectly as applied to surface water supplies, since the coli-aerogenes population of springs, wells and streams may be derived largely from soil.

[1] Department of Bacteriology, University of Illinois, Urbana, Ill.

In the present investigation 52 soil samples were taken at different points over an area about 15 by 20 miles in the central eastern section of Illinois. This section is practically all farm land and is largely under cultivation. The samples were collected during the months of June and July. The general type of soil in this locality is a brown silt loam. The hydrogen-ion concentration does not vary over a wide range from either side of neutrality so that extremely acid or alkaline soils were not encountered.

From a sanitary standpoint the soils should be divided into two groups based on the apparent degree of fecal pollution to which they had been exposed. The first group consisted of samples from ordinary fields under cultivation (corn, oats, wheat, rye, alfalfa, clover), while the second was represented by soil from pastures. The soils constituting the first group were exposed to only chance fecal contamination such as might come from animals employed in cultivating the fields or from dust blown across from neighboring country roads. Very little information was available as to previous fertilizer treatment of the fields, though none of them had been recently manured. The samples which are considered in the second group were taken from pasture lands in which animals were grazing and the soils here represent a rather high degree of pollution. In each case the pastures had evidently been used for this purpose for some time.

In the examination of soil for members of the coli-aerogenes group several methods are available. Portions of the sample may be enriched in lactose broth, or plates may be made directly from suspensions of the soil in sterile distilled water. Each method has certain obvious disadvantages: in the process of lactose enrichment certain types may be overgrown and lost so that a true picture of the relative distribution of the several types is not obtained, while by direct plating many colon group organisms may be missed, especially if they are not particularly abundant. In the present work both methods were used.

Samples of surface soil were collected in sterile wide mouth bottles and transported to the laboratory within a few hours after collection. The following procedure of examination and cultivation was adopted: from each sample approximately 10 grams of soil were transferred with aseptic precautions to a small flask containing 100 cc. of lactose broth, then 1.0 gram and 0.1 gram quantities were inoculated into ordinary lactose broth fermentation tubes. Smaller amounts were examined by direct plating. Suspensions in sterile water were

made and amounts approximating as nearly as possible 0.01 and 0.001 gram of soil were plated directly in Endo medium. Endo or eosin-methylene blue plates were streaked from the lactose enrichment cultures and colon-like colonies transferred to agar slants and to lactose broth for reisolation. Only one culture was picked from each plate unless entirely different types of colon-like colonies were present, in which case one of each was isolated. Such a procedure seemed necessary in order to avoid getting from the plates a number of cultures all of which might have resulted from the multiplication of one

TABLE 1

Summary of results on soil samples examined for coli-aerogenes group

	TOTAL NUMBER SOIL SAMPLES EXAMINED	SAMPLES NEGATIVE	SAMPLES YIELDING COLON GROUP CULTURES	TOTAL NUMBER CULTURES OBTAINED
Cultivated fields	41	7	34	104
Pastures	11	0	11	33

TABLE 2

Occurrence of coli-aerogenes group as shown by isolations from varying quantities of soil

	10 grams.	1 gram.	0.1 gram.	0.01 gram.	0.001 gram.
Cultivated fields (104 cultures)	24	43	25	3	9
Pastures (33 cultures)	10	8	8	0	7*

* All 7 cultures were isolated from one sample.

original cell in a lactose broth enrichment tube. Any colon-like colonies appearing upon the plates which were poured directly from the diluted suspensions of soil were isolated for further study. On many of these plates no colon-like colonies were encountered, though a great many soil forms developed and in some cases the plates were too crowded for use.

It will be seen that, by the foregoing method of examination, different quantities ranging from 10 grams to approximately 0.001 gram of each soil sample were cultured. The results should give some idea of the relative abundance of the coli-aerogenes types on the soils

under investigation. It is realized, of course, that by any available method of cultivation some organisms may be overgrown or otherwise lost and that the results obtained can be regarded as only an approximation of the actual conditions.

A summary of coli-aerogenes isolations from both cultivated fields and pastures is shown in table 1, while some idea of the relative abundance of these types is given in table 2. It is evident that by far the greater number of isolations was obtained from the 10, 1 and 0.1 gram quantities and relatively few cultures were obtained from the smaller amounts. A few exceptions to this were encountered with individual samples, for occasionally cultures were obtained only from the smaller quantities of a particular sample. It seems probable that in these cases the colon group organisms were overgrown by other forms and could not be detected in the larger amounts of soil. This same effect is seen also in a comparison between the number of isolations from the 10 and 1-gram samples from cultivated fields. Here, although an equal number of samples was examined in each case, only 24 cultures were obtained from the 10-gram amounts, whereas 43 were secured from the 1 gram quantities.

Another point relative to the occurrence of the colon group in soil was noted. This was the apparent irregularity in distribution of the organisms in different samples of soil, even when collected from the same general locality. Not infrequently, upon examination of several samples of soil collected from different parts of the same field, cultures would be obtained from the 10, 1 and 0.1 gram quantities of one sample, while from another no cultures at all could be isolated. Evidently the distribution of these forms is far from uniform, even in the same general locality and type of soil. In this connection it should be noted that 7 of the 41 samples from fields yielded entirely negative results, while from a few samples cultures were obtained from a one to one thousand dilution.

All cultures were replated, in some instances a number of times, to insure purity before determining their behavior toward the differential tests. The methyl red, Voges-Proskauer and citrate tests were used and on the basis of these the cultures could be assigned to one or another of the sections shown in table 3. Here we have first the well-known aerogenes-cloacae section, next the Bacterium coli section consisting of cultures which on the basis of the differential tests are similar to fecal Bacterium coli and lastly, the so-called intermediate section comprised of those cultures giving a positive methyl

red test but which differ from the true intestinal coli on the basis of the citrate test (2). In cultivated fields, with only the possibility of chance intestinal contamination, the aerogenes-cloacae types predominated and included slightly over 67 per cent of the colon group cultures obtained from this source. The Bacterium coli type comprised about 23 per cent of the cultures while the intermediate type was found in relatively small numbers. Two atypical cultures were also found. The pastures represent an entirely different condition. Here there was abundant contamination with fecal material and this is reflected in the great increase in the Bacterium coli type which was more abundant than even the aerogenes section. The intermediate type was found less frequently than before. Apparently the normal soil forms have been "snowed under" by the large increase in numbers of the intestinal organisms.

TABLE 3

Showing the proportions of the different coli-aerogenes types found in soils

	CULTIVATED FIELDS (ONLY CHANCE FECAL POLLUTION)		PASTURES (HIGHLY POLLUTED)	
	Number	Per cent	Number	Per cent
Aerogenes-cloacae section (MR−, VP+, citrate +)	70	(67.3)	11	(33.3)
Bact. coli type (MR+,VP−, citrate−)	24	(23.1)	21	(63.6)
Intermediate section (MR+, VP−, citrate +)	8	(7.7)	1	(3.0)
Atypical:				
MR−, VP−, citrate +	1	(0.9)		
MR+, VP+, citrate +	1	(0.9)		
Totals	104		33	

The significance of these results may be brought out further by comparison with a previous investigation (3) in which the same differential tests were applied to a series of coli-aerogenes cultures isolated from the soils of hill tops and mountain tops, where there seemed to be little if any chance of pollution. From a sanitary standpoint the soil of these localities would be ranked ahead of any included in the present study. In such situations the aerogenes section predominated as would be expected, the Bacterium coli type comprised only 2.8 per cent of the cultures, while the intermediates ec-

tion included 31.9 per cent of the cultures. Taken in connection with the present investigation it is clear that the differential tests bring out a correlation between the type of colon group organisms and the degree of fecal contamination.

SUMMARY

From the foregoing results several points are brought out:

1. Members of the coli-aerogenes group were found to be fairly abundant in the soils of cultivated fields and pastures.

2. Their distribution appears to be irregular, some samples yielding negative results, while from other samples cultures were obtained from relatively small amounts of soil.

3. The results of the methyl red, Voges-Proskauer and citrate tests brought out a general correlation between the proportion of the various sections of the colon group and the apparent degree of fecal pollution of the soil. The proportion of the Bacterium coli type (Mr+, VP−, citrate−) increased with the amount of fecal contamination and was highest in the soil from pastures.

REFERENCES

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(2) KOSER, S. A.: Jour. Amer. Water Wks. Assoc., 1924, vol. 12, p. 200.

(3) KOSER, S. A.: Jour. Bact., 1924, vol. 9, p. 59.

AUTOMATIC PRIMERS FOR CENTRIFUGAL PUMPS[1]

By F. H. Bradford[2]

The APCO automatic primer for centrifugal pumps consists of a tank divided by partition in the middle into two parts, one above the other, arranged for connections to the pump. The lower half is connected to the suction and the upper half to the discharge side of the pump.

The purpose of the APCO primer is to automatically prime a valveless pump without the use of a foot valve or any other mechanical contrivance which might be subject to wear and tear or service disabilities. By the use of the automatic primer a horizontal pump may be used on suction lifts to the limit of its ability to raise water by suction.

Automatic primers are usually made of tank iron, but may be made of other materials as the necessities of the occasion may demand. The operation is as follows:

When first installed the lower chamber is filled with water and as the level of the water is above the top of the pump casing, the pump is primed and ready to start. When the pump lowers the liquid in the lower chamber, the air within the top thereof and the suction pipe expands to fill the space and in so doing drops in pressure. Before the suction pipe is uncovered the atmospheric pressure will force the liquid from the vessel to be emptied through the suction pipe into the top of the lower chamber and falling through the body of air therein is drawn out by the pump, which discharges it into the upper tank. When the pump is stopped the air valve at the top of the upper chamber opens and allows the liquid to return by gravity through the pump to the lower chamber, forcing the air back through the suction line, thus flushing the suction line and repriming the system.

Automatic primers are especially useful for automatic or remote control and can be used to advantage where the service requires frequent starting and stopping, such as on automatic sump work.

[1] Presented before the Illinois Section meeting, March 24, 1926.

[2] President, Automatic Primer Company, Chicago, Ill.

They are being used in isolated sewage plants, private water systems, on drainage projects and in fact nearly every conceivable kind of service where there is a suction lift and prompt and dependable priming is a factor of importance.

The use of the automatic primer may be limited by the size of the tank and the space available for installation. On very long suction lines, especially where there is a high suction lift, the size of the primer might necessarily have to be too large for the size of the pump with which it is to be installed, but as centrifugal pumps are located close to the source of supply, the limitations cited are not necessarily of great importance.

Primers are practically fool-proof and if properly installed can not fail to work in accordance with claims made for them for the principle of operation is based on physical laws, and not on mechanical means for accomplishing the desired result. Each size of primer is adapted to a maximum condition or service and naturally the duty to be performed must be within the limit of capacity.

A short time ago we had occasion to prepare new literature and thought it advisable to answer in this literature the questions that are asked most frequently. In examining our files and making a search for questions we were surprised to find that all were practically the same. Answers to them are as follows:

There is no possibility of air binding the pump.

There is no possibility of air binding the primer, as the water which enters from the suction line falls through the air which is trapped in the lower chamber and entrains more than sufficient air to compensate for any air or vapor which might be released from the water when it is placed under vacuum.

The vacuum break connection is made for the purpose of breaking the vacuum on the back flow when the pump is shut down. When the flow of water is reversed, there is a siphoning action which has to be broken or an air pocket might form in the pump which would interfere with the starting operation. The vacuum break introduces air at the top of the suction chamber just as soon as the opening in the discharge line is uncovered on the back flow. Introduction of air at this point allows the water in the suction line to fall and the original equilibrium to be restored. When the pump is operating there is a slight leakage of water back through the vacuum break into the suction chamber, but owing to relative pipe sizes this leakage is usually less than 1 per cent.

Air pockets in the discharge line are unlikely, as any air passed by the pump would accumulate in the top of the upper chamber and escape through the air valve. This air valve is positive and will not pass liquid. The following advantages are claimed for this equipment:

It does away with foot valves.

It has no moving parts with the exception of the float in the air valve.

It is dependable for automatic and remote control.

It does not require manual operation.

It eliminates mechanical equipment subject to wear and tear and service disabilities.

It avoids danger of freezing as the suction line is filled with air when the pump is shut down.

It makes horizontal centrifugal pumps superior to other types for suction possibilities.

It has a low first cost.

COPPER IN THE DISTRIBUTION SYSTEM FOLLOWING WATERSHED TREATMENT[1]

By F. E. Hale[2] and Henry F. Muer[3]

During recent years it has been the practice of the water department of New York City to resort to continuous automatic treatment with copper sulphate of the Catskill water as it passes from Ashokan to Kensico reservoir to prevent seeding the storage reservoir near the City with organisms prevailing in the upper watershed reservoir. The extent of this practice is shown as follows:

1920	3 months	(5 periods)
1921	1 month	(2 periods)
1922	5 months	(4 periods)
1923	6 months	(3 periods)
1924	5 months	(3 periods)

Synura has been present each fall in Ashokan reservoir in small quantity and to avoid any repetition of the experience with synura in the winter of 1921, treatment of the water in the aqueduct has been continuous all winter until about the middle of February. After this date untreated water could not reach the effluent chamber of Kensico reservoir in several weeks or until ice would be off Kensico so that direct treatment of that reservoir could be made if necessary.

Synura appeared as usual last fall in Ashokan reservoir and automatic treatment in the aqueduct with copper sulphate at the rate of one pound per million gallons, 0.12 p.p.m., was started on October 11, 1924 and continued until January 29, 1925. A separate growth of synura prevailed at the same time in Kensico reservoir so that it became necessary to treat the lower portion with the same dosage, which was carried out on October 23, 24, 25 and 27 from the dam to Bear Gutter point or about half way to the influent chamber. The

[1] Presented before the Water Purification Division, Louisville Convention, April 29, 1925.

[2] Director of Laboratories, Department of Water Supply, Gas and Electricity, New York, N. Y.

[3] Chemist in charge, Mt. Prospect Laboratory, Brooklyn, N. Y.

distance between the influent and effluent chambers is about three miles. The depth ranges from ten feet at the influent chamber to one hundred feet at the lower end. The treated portion ranged from fifty to one hundred feet in depth and dosage was apportioned to volume. The water leaving Kensico reservoir passes through Hillview reservoir of 900 m.g. capacity or about one and one-half day's storage at present rate of draft.

Several times during previous experience search had been made for copper in the distribution system of the City, evaporating one and one-half gallons of water for test, and not a trace had been found. This winter it was decided to make a more extended search. Of the regular daily samples collected at Shaft 23, Brooklyn, 200 cc. portions were taken and combined until 4 liters were obtained, representing about three weeks. This composite was analyzed for copper. The procedure began October 19, 1924 and has been continued to date.

On November 24, 1924, a series of samples was taken from the surface water of Kensico reservoir to ascertain the extent of residual synura following the treatment of the previous month. Three samples taken in the upper area from Bear Gutter point to the influent chamber were combined and tested for copper and likewise four samples taken between Bear Gutter point and the dam were combined and tested.

Table 1 shows the results of these examinations.

The astonishing feature is that copper was continuously present until four weeks after the automatic treatment stopped, a period probably roughly equal to the time of flow from influent to effluent chamber. The amounts would indicate either an uneven admixture of the copper with the water or a certain striation of the precipitated copper. The dosage both of the reservoir and in the automatic treatment was 0.12 p.p.m. based on total volume. It seems probable that the copper combines with the organic matter of the microscopic organisms as well as with the alkalinity and may either float or sink or be continuously affected by the winter circulation of the water which takes place from top to bottom all winter. Apparently all the copper fed into the supply came through into the distribution system. The first composite from Shaft 23 probably represents the reservoir treatment but all the others the aqueduct treatment. It will be interesting to note in future whether the same thing occurs in other periods than winter, since real stagnation occurs in summer.

The amounts of copper found were too small to be of sanitary significance. Whether they are of industrial importance, such as in

photography or in dye manufacture, is a question for future decision, considering the experience of Baltimore with small amounts of manganese in the laundry industry.

The method employed in determining these minute amounts of copper was as follows:

The composite samples ranged from 2.3 to 4.2 liters and the weight of copper determined from 0.1 mgm. to 0.5 mgm. As a routine procedure 4 liters was adopted. As the ratio of copper to crystalline copper sulphate is as 1:4, the

TABLE 1

Determination of copper in water supply

DATE	LOCATION	VOLUME OF WATER	WEIGHT ELECT. Cu	TITRATION Cu	†Cu	‡$CuSO_4 5H_2O$
		liters	*mgm.*	*mgm.*	*p.p.m.*	*p.p.m.*
November 24, 1924....	Kensico reservoir, upper area	2.28	0.5		0.22	0.88
November 24, 1924....	Kensico reservoir, lower area	3.16	0.4*	0.10	0.03	0.12
October 19, 1924–November 5, 1924	Shaft 23, Brooklyn	4.25	0.5	0.42	0.11	0.44
November 16, 1924,–December 5, 1924...	Shaft 23, Brooklyn	4	0.2	0.18	0.05	0.19
December 7, 1924–December 26, 1924.....	Shaft 23, Brooklyn	4	0.3	0.22	0.07	0.26
December 28, 1924–January 16, 1925....	Shaft 23, Brooklyn	4	0.1	0.14	0.03	0.12
January 18, 1925–February 6, 1925.....	Shaft 23, Brooklyn	4	0.3	0.30	0.08	0.30
February 8, 1925–February 27, 1925.....	Shaft 23, Brooklyn	4	0.3	0.20	0.06	0.25
March 1, 1925–March 20, 1925.....	Shaft 23, Brooklyn	4	0.0	0.05	0.01	0.04
Average.....			0.24	0.22	0.06	0.23

* Deposit dark and ammonia blue color slight.

† Average of weight and titration, with exception of reservoir results.

‡ Calculated to form in which it is applied.

amount of copper determined as Cu equals parts per million direct of copper sulphate as applied.

The composite, acidified with 5 cc. of 1:1 nitric acid, is evaporated to dryness on a water bath in a platinum dish. The residue is gently ignited by fanning with a gas flame until the small amount of organic matter remaining is burned off. The evaporation with nitric acid destroys most of the organic matter and oxidizes any iron to ferric condition.

The residue is now transferred to a 3-inch porcelain evaporating dish by treating with 5 cc. of hot 1:1 nitric acid and thoroughly scrubbing with a policeman, repeating the scrubbing with a second 5 cc. of acid and washing with two portions of hot water.

The contents in the porcelain dish is again taken to dryness to get rid of excess nitric acid and thoroughly dehydrate silica. The residue is moistened with 1 cc. of 1:1 nitric acid, diluted with 15 cc. of hot water, filtered on a small filter and washed with successive small portions of hot water from the top down. The filtrate and washings are caught in a 60 cc. non-sol beaker, volume about 30 cc. This process gets rid of the large bulk of insoluble solids from the gallon of water taken.

The filtrate is now treated with 1:1 ammonia in distinct excess to precipitate iron and hold copper in solution, boiled, settled, filtered on a small filter paper, and washed with hot water made slightly alkaline with ammonia. The filtrate is transferred to a 3-inch porcelain evaporating dish again, concentrated to about 10 cc. to precipitate the last traces of iron, filtered through a small filter, washed with successive portions of hot water from the top down. The filtrate and washings amount to 20 cc. and are caught in a 60 cc. non-sol beaker.

Then 5 cc. of 1:1 nitric acid and 5 cc. of saturated solution of potassium sulphate are added. The latter assists copper to deposit completely in a bright clean manner. Electrolysis takes place over night (sixteen hours) using 110 volt D. C. lighting current through a 10 watt lamp, i.e., 0.10 ampere. The electrodes used are platinum spirals (of #16 B. & S. gauge wire) weighing about 13 grams each. About 1 inch is immersed in the liquid. Copper may be readily seen down to 0.1 mgm. There should be no odor of ammonia in the liquid after electrolysis due to reduction of the nitric acid; if so the deposit will be black and oxidized. The coils are washed with distilled water with the current on while lowering the beaker until free from the liquid. This is a necessary precaution as it does not take nitric acid long to dissolve traces of copper with the current off. The coils are dipped in alcohol, heated over a gas flame until the alcohol has evaporated without igniting, cooled in a desiccator and weighed.

As a check the deposit is dissolved by rolling the cathode in 3 cc. of 1:1 nitric acid in a test tube and washing in 3 cc. of distilled water in another tube. The washing is added to the acid solution and nitrous oxides boiled off, then made alkaline with 1:1 ammonia. Even traces of copper in small volume give a blue color and an estimate of amount may be made by comparing with known amounts of copper solution similarly treated.

As a further check the ammoniacal solution is acidified with acetic acid in the test tube, treated with a crystal of potassium iodide, the size of a pea, and the resulting iodine set free titrated with N/100 thiosulphate, using a 2 cc. pipette graduated to 0.02 cc., and starch solution as indicator. Each cubic centimeter N/100 thiosulphate equals 0.635 mgm. Cu.

These two checks are of advantage in denoting the purity of the copper deposit. The agreement between the electrolytic weight and the titration is shown in the table and is reasonably close.

FLOW OF WATER IN PIPES[1]

By Hiram F. Mills

A REVIEW BY ALLEN HAZEN[2]

This book of 236 beautifully printed quarto pages presents the results of more than fifty years study of hydraulic problems by a man of unusual capacity for observation and analysis.

The material relates mainly to the flow of water in pipes, and was intended to be the first part of a complete treatise on hydraulics, but these pages represent all of the work that the author's strength and life permitted.

The studies were made in the first place to find means for accurately measuring the water supplied by the Essex Company of Lawrence, Mass., to the various mills on its canals for power. The work was afterwards greatly extended by Mr. Mills, we may believe, for the pure love of finding the exact truth. We know that for a period of many years the project of a treatise on hydraulics lay dormant while even more important matters occupied his attention.

The statement of experimental methods used in 1875, beginning on page 147, leaves one in doubt which to admire most, the sturdy, simple measures taken to find out the exact truth, or the clear, concise English in which the methods are pictured. These pages bring to the writer the memory of what he saw at Lawrence during the years when he helped Mr. Mills with other matters. He remembers the numerous observing stations manned by careful, conscientious young men, observing water levels at predetermined intervals, and writing down the results to be plotted and averaged and compared, until everything was checked and accounted for beyond a possible doubt. The writer knows something of the thorough methods of Mr. Mills for they were also applied to the work which he did at Lawrence. Each of the experimental results stated in the tables

[1] With historical and personal note by John R. Freeman and introductory outline by Karl R. Kennison. Privately printed.

[2] Consulting Engineer, New York, N. Y.

is the average of many single tests, and one feels that the results can be depended upon for such strict accuracy as is rarely found in the records of experimental work.

The amount of new experimental material on the flow of water in pipes is very large, and its character is of a high order. It includes the records of flow in small brass pipes made by Mr. Mills himself, and in larger brass pipes by his former assistant, Mr. John R. Freeman, extending to pipes as large as 4 inches in diameter, and to velocities as high as 30 feet per second. The text gives some idea of the care taken to prevent roughness at the joints and on the interior surfaces, and the coefficients that were obtained, not exceeded by any since obtained, are convincing evidence of the thoroughness with which all roughness and obstruction were avoided.

Other experiments by Freeman on wrought iron pipes from the smallest commercial sizes up to 8 inches in diameter, and with velocities extending to 13, and in some case to over 20 feet per second are recorded. Other experiments on wrought iron pipe by J. B. Francis, cover a much shorter range of velocities, and there are experiments on cast iron pipe, new and old by Mr. Mills, and by several of his assistants and associates.

The experiments upon one line of specially prepared 12-inch cast iron pipe made during the years from 1875 to 1882, are unique in their thoroughness. No less than 1045 separate determinations are summarized in the tables of results.

To the rich data made available to Mr. Mills, he added the results of published experiments which he believed to have been reliable, and the whole mass of data was then analyzed to determine as far as possible the laws of flow. Many matters are taken up and the business developed to form a complete treatise on the flow of water in pipes.

All the elements of flow are discussed, including size, material, age and condition, but, from the present standpoint, perhaps the matter of greatest scientific interest to us is the study of the relations between velocity and slope or friction. The experiments available covered a remarkable range from low to high velocities with the greatest accuracy. The method of study was unique and would be only possible with the very best of data. It is carried out in a way that, as far as the writer knows, has never been elsewhere attempted.

Below the critical velocity, the friction increases as the first power of the velocity. This old law Mr. Mills found to almost exactly

represent the facts. At higher velocities the friction increases nearly as the second power of the velocity, but it is not exactly the second power. It is usually some fractional power materially less than the second power. These small and varying deviations from the second power could not be accepted by Mr. Mills without adequate explanation.

There was much of the mystic in his makeup, and with Swedenborg, he regarded water as the material emblem of Truth. No effort was too great to find out exactly what took place and why.

His description of the flows near the critical velocity as determined by piezometer measurements and otherwise, is one of the most interesting things to be found in this remarkable volume. His study shows that passing upward, as the critical velocity is passed, there is not an abrupt change in the method of flow, but that, instead, there is a gradual introduction of a rolling of the water and a new element of resistance growing out of it not existing at lower velocities, and this new element increases exactly as the square of the velocity, but does not make up the whole of the resistance, for some of the conditions of flow below the critical velocity still continue at higher velocities and are only gradually displaced. Even at full ordinary velocities an appreciable amount of the conditions of the low flows remains, especially with pipes that are quite smooth.

An ingenious mathematical analysis of the record of each pipe separates these elements and shows the amount of each. Charts show graphically how and when the changes come about. There is finally presented a table on page 165 which shows, among other things, how the elements operating at lower velocities and depending upon temperature and viscosity persist in some measure in smooth pipes and in smaller measure in rough pipes at higher velocities. From all this it is easy to see that what we have long known and have expressed roughly by fractional exponents, is really based upon deep-seated laws of flow.

In studying the flows near and for some distance above the critical velocity, Mr. Mills has developed two intermediate formulas to cover the transition stage, and, with these, for a given pipe, there are in all four formulas of flow, one for the range below the critical velocity, two for intermediate or transition stages, and the last for higher velocities. It is not to be supposed that these formulas will displace the ordinary short-cut approximate methods in common use, but it is certainly interesting to see how apparently erratic

variations near the critical velocity can be explained and are found to be parts of one harmonious system.

The writer remembers that in 1892, as he was making some hydraulic calculations for Mr. Mills, he was given a paper showing how those calculations were to be made. This remained among some old prized papers until long afterward. In 1919, he came across it and was struck anew with the merit of the idea which it represented. He called Mr. Mills' attention to the matter at the time and suggested publication and received from Mr. Mills a kindly letter in which it was explained that Mr. Mills hoped to publish the whole work some time and that in the meantime he wished to have the matter held confidential. Needless to say the wish of Mr. Mills was respected, but notwithstanding this, it would be difficult to say to what extent the ideas of the writer and perhaps of others have been influenced by Mr. Mills' work, and to what extent his ideas have found expression and extended use, even though the publication was so long delayed.

Our most cordial thanks are due to Mr. Freeman and to Mr. Kennison for making this material available to us, and it is to be hoped that the announced intention of presenting an abstract to the American Society of Civil Engineers of which Mr. Mills was an honorary member will be carried out.

WATER CERTIFICATES TO FINANCE WATER SUPPLY PLANTS IN ILLINOIS[1]

By Paul E. Green[2]

It frequently occurs that a municipality, although vitally in need of enlargement of its source of water supply, is unable to finance a new plant. The bonding power of Illinois municipalities is limited to 5 per cent of the assessed valuation. Assessing authorities, for political reasons, usually strive to maintain this valuation as low as possible, with the idea that they are keeping down taxes. This of course is only very narrowly true, but the net result is that the municipality has very low bonding power for needed new construction. Taxes are just about as high as they would be in any case, since the rate must be high, and all revenue which can be raised is used for current expenses. A study of tax rates and valuations is very illuminating.

The Illinois law provides for the issuance, under certain circumstances, of water certificates for the purchase, construction, or enlargement of a water plant. There are several acts under which this may be done, but the one most commonly used is that entitled "An Act authorizing cities, towns and villages to build, purchase or extend water supply systems for public and domestic uses and to provide for the cost thereof." Approved April 22, 1899, and in force July 1, 1899. In payment for such building, purchasing or enlargement the municipality may issue certificates of indebtedness, limited in their payment solely to the water fund provided for in the Act. These certificates of indebtedness bear interest at a rate not exceeding 6 per cent and shall be issued for not less than par.

The Act further provides for a schedule of rates, a referendum if 20 per cent of the voters so petition within three weeks of passage of the ordinance, and that the proceeds arising from the operation of the system shall be paid into a water fund, out of which the certificates of indebtedness, or as they are usually termed the water certificates, shall be paid. This water fund must not be used for any

[1] Presented before the Illinois Section meeting, March 24, 1926.

[2] Consulting Engineer, Chicago, Ill.

purpose except to retire these certificates or to pay the necessary operating expenses of the system, and the rates may not be reduced during the life of the bonds.

It is further provided that a mortgage deed of Trust of the water works system may be executed and acknowledged and recorded in the same manner as a mortgage on private property.

In case there is default in payment of the principal or interest, the trustee is authorized to take over the operation of the plant and, if necessary, to raise the rates, and finally to sell the plant in order to satisfy the provisions of the trust deed. Furthermore, if it becomes necessary to sell the plant the municipality is not permitted to construct or operate, or authorize any other person or corporation to construct a system of water works.

It is evident that the intention of the framers of this Act was to provide a means of financing the construction of a water works plant as a public utility, able to stand on its own feet and show an actual profit of sufficient amount to pay for itself. A number of cities and villages in Illinois have taken advantage of the procedure, among which may be mentioned Marion, Carbondale, Herrin, Lemont, Lockport, Brookfield, Glenview, Carterville, Quincy, and probably several others.

The Act has some concealed dynamite in it, and in some cases some rather unusual legal difficulties have been encountered. No part of the system paid for by other means can be included in the mortgage. Some attorneys, whose opinion as to the legality of municipal issues in Illinois is essential if the issue is to be disposed of to advantage, have taken the position that in spite of the fact that the municipality is not, under the Act, obligated as a whole, the issue must be considered as coming under the constitutional limitation of 5 per cent. While they do not condemn the method, they fear it is unconstitutional and will not render an opinion. Since the cost of the works contemplated under the water certificate plan may be more than the constitutional limit, it is obvious that this is a pretty serious obstacle. It should be emphasized that these water certificates or bonds are payable out of the proceeds of the operation of the plant itself and that the only security is the plant. Because of the position taken by such attorneys, even if the municipality had previously voted a general bond for any purpose and such bonds have not been sold prior to the sale of the water certificates, it becomes difficult to secure an acceptable legal opinion on the prior bonds. While other

eminent legal authorities will approve of the water certificates, their opinion is not acceptable on general bonds and the corporation is thus between the devil and the deep sea. Hence, any municipality intending to use the water certificate act would do well to issue and sell its general bonds first.

These water bonds have not been considered first class paper, and have been disposed of at prices varying from 75 to 95. Because of this fact, and also because engineers have not always been consulted in the matter, the practice has grown up of making it a contractor's job rather than a city or engineer's job. The author is of the opinion that such a result is vicious and unnecessary. The law requires that the certificates or bonds shall be issued at par. This provision has been seized upon as making it necessary that the contractor must take the bonds, sell them secretly at a discount, (which is no one's business) and bid accordingly. He handles the entire issue and pays the fees of the engineer and attorney. Such a method means that the usual procedure is reversed, and instead of the city holding the purse strings the contractor holds them and dictates, in a large degree, to the engineer who supervises the work.

The same arguments which are used here would hold for special assessment bonds, but in practice have been found to be erroneous. There is no question but that properly drawn plans and carefully worded specifications can as completely keep the control of the water improvement in the hands of the proper city officials, as are other improvements. Because of this abnormal situation contractors have actively promoted water supply jobs, submitted very general and inadequate plans and specifications prepared by engineers on a contingent basis, and at times have secured the work. Some of it has been undoubtedly badly done and exorbitantly charged for.

The idea back of this method of financing water obligations is sound and provides a means of securing an adequate water supply for cities and villages which would have difficulty in securing it otherwise. It would seem as if a test cast brought to the Supreme Court on its merits, in which the issue is clean cut, would clear the situation amazingly. The decision should either demolish the act or so clear the air that the securities would be placed in an unassailable position. Undoubtedly this will occur in time, but by that time the present rather vicious mode of handling these bonds may have become so settled that it will be difficult to alter the procedure. It is believed,

therefore, that any municipality which takes advantage of this Act should proceed as follows:

1. It should employ competent engineers and attorneys to handle the work without reference to any contractors, and not on a contingent basis. This would result in

(*a*) A minimum of expense, since it is not necessary that complete detailed plans be prepared before the necessary legislation is passed by the municipal body.

(*b*) Very decided decreased legal costs, since the procedure is simple, not nearly as complicated as the Local Improvement Act, and requires no more legal work than is required in a general bond issue. The preliminary legal and engineering fees should not exceed about one per cent. Under the prevailing method the engineering fees have been less, but the legal fees much greater, as our legal brethren are accustomed to contingent fees.

2. It should finance, if possible, some separate part of the improvement by means of a general bond issue, and issue and sell the general bonds first. Thus the land and the reservoir may be purchased from the proceeds of the water certificates, while the pumping plant, located elsewhere, may be constructed from the proceeds of the general bond issue. If this procedure is followed, genuine competitive bids may be obtained on properly prepared plans. The working details can be drafted after proper legislation is so advanced that the contingent fee is eliminated. The matter of discount need cause no worry, since it will either disappear entirely as the procedure becomes more settled, and previous issues of such securities have been paid off, or it may be legally and properly taken care of by carefully drawn clauses in the specifications and bidding sheet.

If it be assumed that the legal procedure has been properly observed, the most important part of the legislation providing for improvements under this Act is that which schedules the rates to be charged for water, the provision for retirement of the certificates or bonds themselves, and the allocation of the earnings between the new and old plants. There is no limit set in the law as to the amount of the issue, but it is obvious that one based on inadequate earning capacity and which provides for very long term bonds will be difficult to sell, and even if sold will bring a low price. Bond brokers are not over scrupulous as to the amount of the issue, provided any sort of showing can be made as to the operating profits. The more bonds

that are issued, the greater is the commission. The price paid will be based on the revenue, and, if in their opinion, the revenue is overestimated and the life of the bonds too long, it will be reflected very decidedly in the price offered for the issue.

The engineer who is preparing a rate schedule must analyze the earning capacity of his water plant very completely. He must so adjust his rates as to encourage the use of water but not its waste, and furthermore must so arrange his brackets or divisions that the maximum amount of revenue will be obtained from the operation of the plant. This can only be obtained by a detailed study and analysis of the past individual meter readings and revenues. Here enters also the question of allocation of the earned revenue between the original or general bond issue plant and the new one; for this method of financing practically presupposes an existing plant with an established business. If such analysis is carefully and competently made and the fixed annual cost so adjusted that the burden is minimized during the first few years of operation, the issue can be made a decidedly attractive one. If the total issue is so calculated that the revenues, after deducting operating costs, exceed by approximately 50 per cent the bond requirements, the issue can be sold at a figure not far below par, and when practice is stabilized there can be but little question that this class of securities will approach and pass par.

The effect on a municipality of successfully financing an improvement under this Act is to improve the efficiency of its water plant. It is subject to the scrutiny of the Trustee, and must produce sufficient revenue to retire the bonds. Under this law the revenue cannot be diverted and all water must be metered, and no free water can be furnished to anyone. The net result is an efficiently and economically conducted public utility.

RAPID FINE SAND FILTRATION[1]

FREDERICK E. FIELD:[2] Mr. Blaisdell has given us a paper which should be of interest to those who are engaged in the design, construction or operation of filtration works.

With regard to the desirability of placing the filter sand, when in a wet condition, in the bed and the removing of all entrained air, we have often noted that filter specifications require the placing of filter sand in thin layers and the settling of each layer by flooding by an upward flow of water, at a low rate, and also that before a drained filter is placed in service, it is common practice to backfill at a slow rate to remove the entrained air.

Mr. Blaisdell, however, has gone a step in advance and shown by actual experiments the need of particular care in these respects, if filters of fine sand are to operate satisfactorily at high rates.

REVERSE FLOW TESTS

As the writer coöperated with Mr. Blaisdell in the "high rate" and "reverse flow" tests at the Montreal Filtration Works, he finds Mr. Blaisdell's statements in regard to these of much interest, since it is the first time reference to these tests and experiments have been noted in publications.

Mr. Blaisdell's description of the tests with the 18-inch experimental filters at Montreal is so complete as to make further comments of little value.

He did not include however with his paper any of the charts therein mentioned, and possibly some of these will make these experiments of more general interest.

We therefore include charts for the 18-inch Experimental Filters Nos. 1 and 2 for the months of September and October, 1921.

These show the average daily rate of filtration and the gradual increase of the loss of head as the filters became clogged. They also show the reduction in loss of head by means of the "reverse flow."

[1] See JOURNAL, December, 1925, page 581.

[2] Filtration Engineer, Water Board, Montreal, Quebec, Can.

In addition, the October charts show the daily turbidity of both the "raw" and the "filtered" water and the percentage of turbidity reduction.

During September both experimental filters were supplied with water of low turbidity, but during parts of October the turbidity of

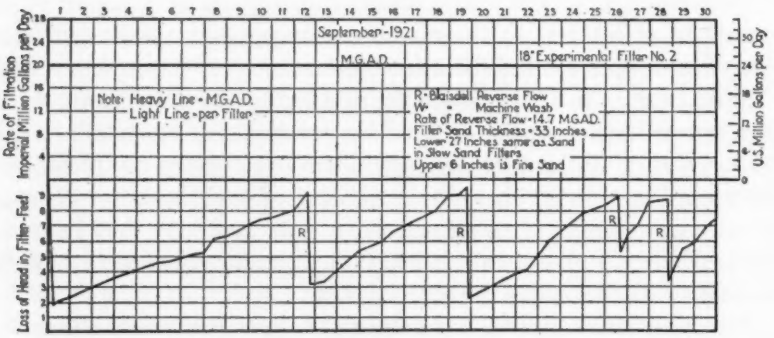

September-1921
M.G.A.D.
18" Experimental Filter No. 2
Note: Heavy Line = M.G.A.D.
Light Line = per Filter
R-Blaisdell Reverse Flow
W = Machine Wash
Rate of Reverse Flow = 14.7 M.G.A.D.
Filter Sand Thickness = 33 Inches
Lower 27 Inches same as Sand in Slow Sand Filters
Upper 6 Inches is Fine Sand
Rate of Filtration Imperial Million Gallons per Day
Loss of Head in Filter-Feet
U.S. Million Gallons per Day
R

FIG. 1. BLAISDELL REVERSE FLOW FILTRATION TESTS

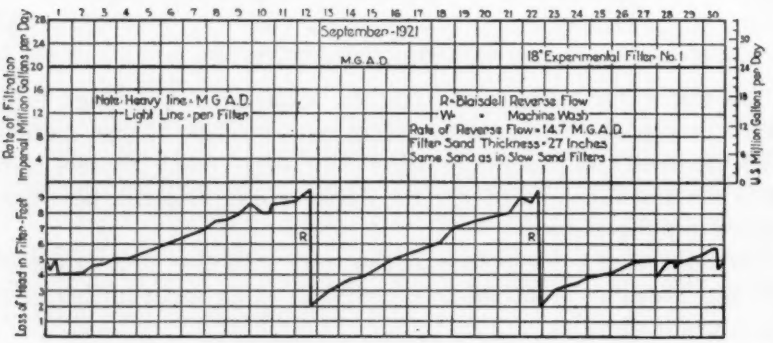

September-1921
M.G.A.D.
18" Experimental Filter No. 1
Note: Heavy line = M.G.A.D.
Light Line = per Filter
R-Blaisdell Reverse Flow
W = Machine Wash
Rate of Reverse Flow = 14.7 M.G.A.D.
Filter Sand Thickness = 27 Inches
Same Sand as in Slow Sand Filters
Rate of Filtration Imperial Million Gallons per Day
Loss of Head in Filter-Feet
U.S. Million Gallons per Day
R

FIG. 2. BLAISDELL REVERSE FLOW FILTRATION TESTS

the St. Lawrence River water was artificially increased to as high as 120 p.p.m. The decreased lengths of runs and the results of the "reverse flow" under the change of conditions are clearly indicated on the charts.

REVERSE FLOW TESTS ON FULL SIZE FILTERS

The results of the tests with the 18-inch experimental filters made it desirable to conduct similar tests on the final slow sand filters of the Montreal Plant.

The Montreal Plant is designed for, and normally operated by, a system known as "Double Filtration," which means that the effluent from the rapid sand pre-filters passes through the final slow sand filters before entering the filtered water basin.

These final filters are 340 feet long and 57 feet wide (center to

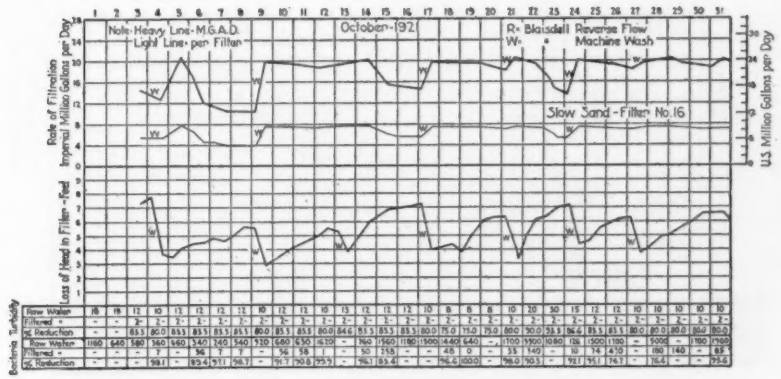


FIG. 3. BLAISDELL REVERSE FLOW FILTRATION TESTS

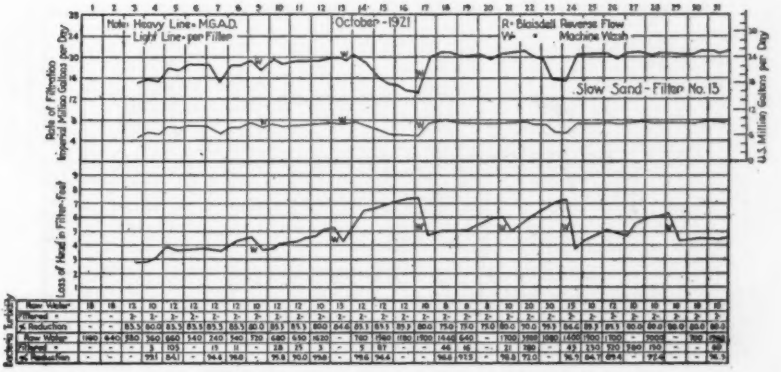


FIG. 4. BLAISDELL REVERSE FLOW FILTRATION TESTS

center of dividing walls) and are each divided by columns, supporting the roof, into 3 longitudinal bays.

Each final filter, with a sand area of $\frac{3}{8}$ acre, has for filter material, 12 inches of graded gravel and 27 inches of filter sand having an effective size of 0.25 to 0.35 mm.

The underdrainage system consists of two half-round 8-inch tile

laterals in each transverse bay which discharge into a central main collector 30 inches in diameter and extending the entire length of the filter below the floor level.

The filter washing is done by Blaisdell Washing Machines which run on longitudinal tracks in each bay. These machines rake and

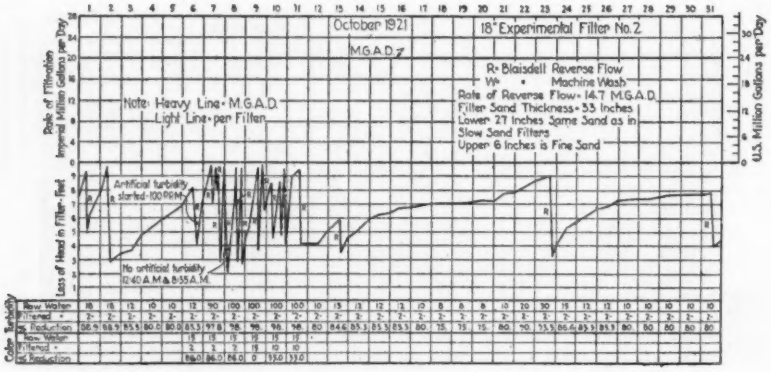

October 1921
M.G.A.D.
18" Experimental Filter No. 2
R- Blaisdell Reverse Flow
W- Machine Wash
Rate of Reverse Flow - 14.7 M.G.A.D.
Filter Sand Thickness - 33 Inches
Lower 27 Inches Same Sand as in Slow Sand Filters
Upper 6 Inches is Fine Sand
Note: Heavy Line - M.G.A.D.
Light Line - per Filter
Artificial turbidity started - 100 P.P.M.
No artificial turbidity 12:40 A.M. to 8:55 A.M.
Rate of Filtration Imperial Million Gallons per Day
U.S. Million Gallons per Day
Loss of Head in Filter-Feet
Color Turbidity
Raw Water
Filtered
% Reduction

FIG. 5. BLAISDELL REVERSE FLOW FILTRATION TESTS

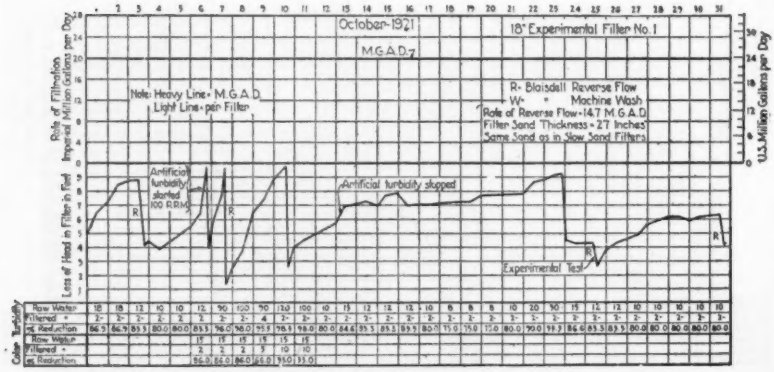

October-1921
M.G.A.D.
18" Experimental Filter No. 1
R- Blaisdell Reverse Flow
W- Machine Wash
Rate of Reverse Flow - 14.7 M.G.A.D.
Filter Sand Thickness - 27 Inches
Same Sand as in Slow Sand Filters
Note: Heavy Line - M.G.A.D.
Light Line - per Filter
Artificial turbidity started 100 P.P.M.
Artificial turbidity stopped
Experimental Test
Rate of Filtration Imperial Million Gallons per Day
U.S. Million Gallons per Day
Loss of Head in Filter-Feet
Color Turbidity
Raw Water
Filtered
% Reduction

FIG. 6. BLAISDELL REVERSE FLOW FILTRATION TESTS

wash the sand to any desired depth, leave the sand clean and uniform and pump away to the drain all dirt and foreign matter which has accumulated since the last washing.

The normal rate for which the filter was designed is $8\frac{1}{4}$ m.g. (Imperial) or 10 m.g. (U. S.) per acre per day.

This description of the final filter will indicate under what conditions the "reverse flow" tests were conducted.

Four of the sixteen final filters were used in these tests, and we include four of the record charts, (i.e., those for October, 1921), to illustrate the results of the experiments.

Filter No. 2, was operated at the normal rate of 10 m.g. (U. S.) per acre per day for a comparison with filters Nos. 13, 15 and 16,

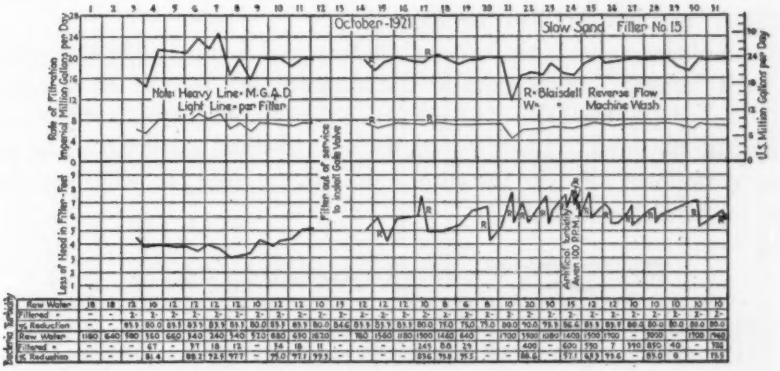

October-1921
Slow Sand Filter No 15
Note Heavy Line - M.G.A.D.
Light Line - per Filter
R - Blaisdell Reverse Flow Machine Wash
Rate of Filtration Imperial Million Gallons Per Day
U.S. Million Gallons per Day
Loss of Head in Filter-Feet
Filter out of service to isolate Gate Valve
Raw Water
Filtered
% Reduction
Backing Turbidity

FIG. 7. BLAISDELL REVERSE FLOW FILTRATION TESTS

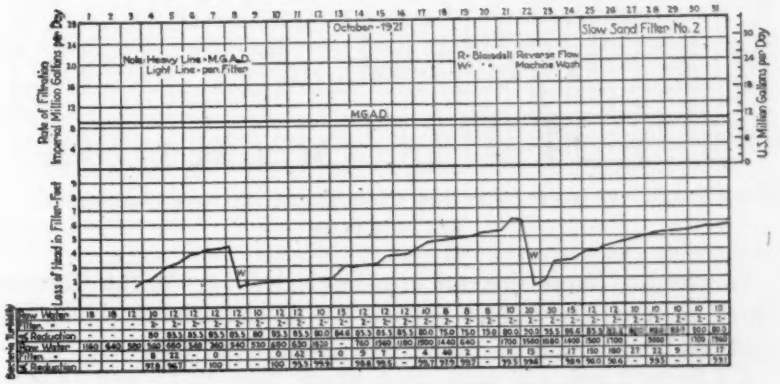


FIG. 8. BLAISDELL REVERSE FLOW FILTRATION TESTT

which during these tests were run at the average rate of 24 m.g. (U. S.) per acre per day.

Filter No. 15 was especially equipped for the "reverse flow" tests while filters Nos. 2, 13 and 16 were washed when required by the Blaisdell washing machines. Each of these charts show for each day of the month, the rate of filtration, the loss of head, the time and

results of "Machine Wash" or "Reverse Flow." Each chart also gives the daily record of turbidity of "raw" and "filtered" waters and the "bacteria count" in both raw and filtered waters with percentages of reduction in each case.

Two other charts are included, both indicating graphically, the comparison between the results obtained by the regular "Machine Wash" and by the "Reverse Flow."

All of these charts are self-explanatory and require little comment.

All "reverse" flows were at the approximate rate of 15 m.g.a.d. (U. S.) or a vertical rise of about $\frac{3}{8}$ inch per minute, as per instructions by Mr. Blaisdell. The rise was, by such tests as could be made, almost uniform all over the filter, notwithstanding the wide spacing of the lateral collectors.

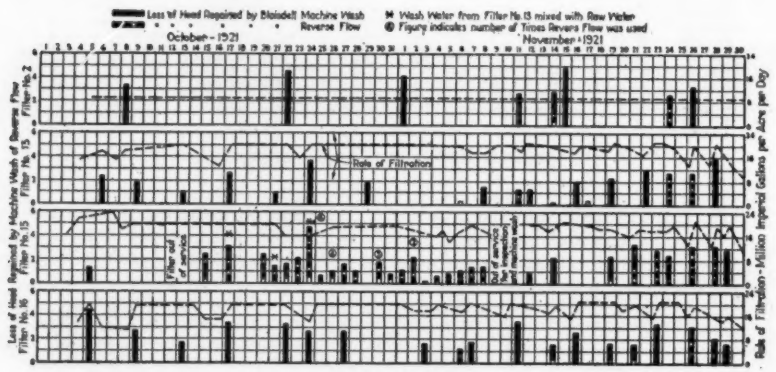

Loss of Head Regained by Blaisdell Machine Wash
Reverse Flow
Wash Water from Filter No 13 mixed with Raw Water
Figure indicates number of Times Revers Flow was used
October - 1921
November - 1921
Rate of Filtration
Filter out of service
Rate of Filtration - Million Imperial Gallons per Acre per Day

FIG. 9. BLAISDELL REVERSE FLOW TESTS, MACHINE WASH AND REVERSE FLOW

For our final filters, this rate of 15 m.g.a.d. (U. S.) for the "Reverse Flow" required about 4000 gallons (U. S.) per minute, which was obtained from a pump purchased and installed for these tests.

On figure 9 you will note, that filters, Nos. 13–15 and 16 were operated at approximately the same rate, i.e. 20 m.g.a.d. (imperial), but that for a period of about one month or from October 5 to November 8, "Reverse Flows" on filter No. 15 took the place of seven (7) "Machine Washes" on filter No. 13 and eight (8) "Machine Washes" on filter No. 16.

In studying and analyzing the data on all these charts it should not be forgotten that these tests represent only preliminary experiments, undertaken only a few months after Mr. Blaisdell had first

conceived of the idea that his so called "Reverse Flow" might be of value.

In pioneer work of this kind where there are no precedents for guidance, progress is necessarily slow and mistakes often made.

About five months time was spent on these experiments at the

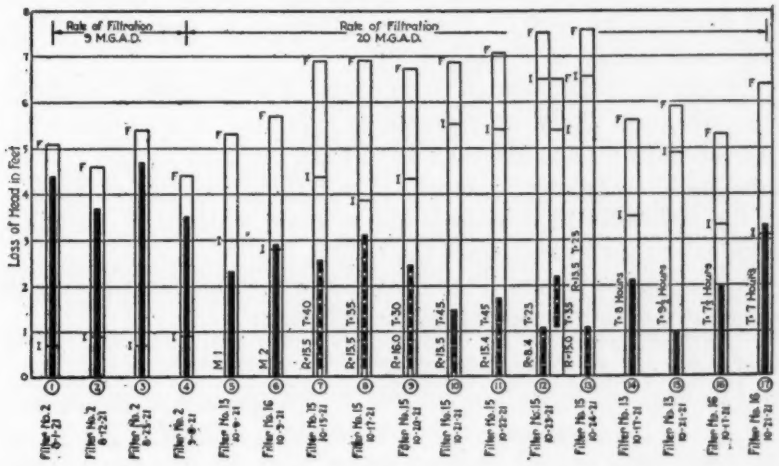


FIG. 10. BLAISDELL REVERSE FLOW TESTS, MACHINE WASH VS. REVERSE FLOW

F = Final Loss of head in filter before Blaisdell machine wash or reverse flow.

I = initial loss of head in filter after Blaisdell machine wash or reverse flow.

Solid black column = loss of head regained by Blaisdell machine wash.

Alternate black and white column = loss of head regained by Blaisdell reverse flow.

R = rate of reverse flow in million imperial gallons per acre per day (m.g.a.d.)

T = time of reverse flow in minutes.

M.1 = washing machine no. 1.

M.2 = washing machine no. 2.

Column 12 = combined reverse flow (i.e., second reverse flow immediately following first reverse flow). Note increase in loss of head regained by second reverse flow.

Note: Filter 15 had last machine wash on October 5, 1921. Since this date filters 13 and 16 have each had four machine washes. Moreover the dirty wash water from filter 13 has been applied to incoming water to filter 15 three times (i.e., October 9, October 17 and October 21) since October 5, 1921.

Montreal Plant, and the cost was considerable, as the filters, piping and water supply needs were not entirely suitable, which made it necessary to purchase and install much equipment.

We also found that filter No. 15 was somewhat abused by the "reverse flow" tests, as conducted, and required much extra work by the Blaisdell washing machines to again obtain the same condition of the sand bed as existed prior to these experiments.

During and subsequent to the experiments supervised by Mr. Blaisdell, Messrs. Kilpatrick and Harrington of the filtration staff did some similar work for their own information, and some of their observations may be of interest.

The initial loss of head in filters operated at low rates is much less than when the filters are operated at high rates of filtration, which may account for the greater loss of head regained by the "reverse flow" on filters having low rates. The varying elevation of the water in the main effluent conduit is also a factor which may explain to some extent the wide range in the results.

Averaging the results of the reverse flow tests on filters having the same rates of flow, we obtained the following:

Loss of head regained by reverse flow

TEST DATA	RATE OF FILTRATION, M. G. A. D. (IMPERIAL)		
	1½	9	20
Number of tests	35	3	18
Average final loss of head, feet	7.77	5.84	6.83
Average initial loss of head, feet	3.76	3.16	5.43
Average head regained, feet	4.01	2.68	1.40
Maximum head regained feet	6.38	2.22	3.28
Minimum head regained, feet	1.22	2.55	0.05

Mr. Blaisdell advises a "reverse flow" at the rate of 15 m.g.a.d. or about $\frac{3}{8}$ inch rise per minute. Some tests at Montreal with a vertical rise of $\frac{1}{8}$ inch per minute produced results not greatly different from those with higher rates of reverse flow.

The "reverse flow" has not been used at the Montreal Filters since the completion of the Blaisdell experiments for two reasons:

1. The gallery piping and water supply available are unsuitable for the reverse flow.

2. There has been no necessity for the use of the reverse flow.

Under normal operating conditions when the "double filtration" system is in use, the final filters require cleaning only about once each month. As two Blaisdell washing machines are available for this work, the filters are easily maintained in a condition for effective

service. In case of emergency, with one of the washing machines out of service, the "reverse flow" could be used to maintain full capacity of the filters under peak loads.

CONCLUSIONS

1. The tests made and the data thus obtained are not sufficient to establish how the "reverse flow" can be used most effectively, but indicate its possible value under certain conditions. Further experimental work may result in its more general application.

2. The "reverse flow" should not be used carelessly or when there are no means available to repair any damage to the sand bed occasioned by its improper use.

At the Montreal Filters any detrimental disturbance of the sand bed can easily be repaired and the filter restored to a satisfactory condition by one or more passages of the Blaisdell washing machines.

3. From the results obtained from "reverse flows" with a very small vertical rise per minute in the filter it would appear that the principal functions of the "reverse flow" are to remove any entrained air, and reduce, to some extent, the compacting of the sand due to the previous operation of the filter.

4. The quantity of wash water required for the final filters at Montreal is less than 0.1 per cent of the water filtered, and this wash water is the raw water above the sand at the time of wash and not filtered water.

Therefore no appreciable savings would result in this respect by the general use of the reverse flow.

Mr. Blaisdell mentions that the results of operation at the Eastman Kodak Company's filter plant are "satisfactory." It would be of interest to have details of the results at this plant, which operates at a rate of 16 m.g.a.d. and also to know if the "reverse flow" is a feature of the operation.

The writer is hopeful that Mr. Blaisdell's paper together with the additional information concerning the "reverse flow" tests at Montreal, now presented, will open the door to an instructive discussion of the subject which will be of mutual benefit.

SETH M. VAN LOAN:[3] Mr. Blaisdell's paper offers three subjects anyone of which is of vital interest to the operation of filter units approaching an acre in size and in which the sand depth, size and grad-

[3] Deputy Chief, Bureau of Water, Philadelphia, Pa.

ing has been designed and placed according to the general standard practice.

First: The author's reference to fine sand and its value in reduction ability deals more or less in a specific way with waters of a medium turbidity with a possible peak of 300 p.p.m. There is a broad difference in operating on the 6 m.g.a.d. basis and at 25 to 50 m.g.a.d. rate. Further reference might be made to the range the author announces as the possibilities of the use of fine sand. It would be of interest to have additional data relative to the operation at a 50 m.g.a.d. rate in which may be shown the turbidity and bacteria content of both applied water and effluent.

The applied and effluent waters to the Philadelphia filters, selecting the last calendar year (1925) for results, have averaged 7 and 0 respectively in turbidities, and 8300 and 4 respectively in bacteria. Recent tests of sand indicate the loss of finer particles, the analyses registering from 0.30 to 0.46 mm. in effective size and 1.98 and 2.16 in uniformity coefficient. Specificatons at the period of construction required an effective size of 0.32 m.m. and a uniformity coefficient of 1.65 with the under drain and outlet piping designed for a 6 m.g.a.d. rate. The rates at the various filter plants on a yearly average will register 2.8 to 3.4 m.g.a.d. The period of operating activity of these filters with the washing of sand necessary for service has reduced the amount of fine content in the first deposited sand. The practice in Philadelphia has been to build on the surface of fresh sand by operating upon a graduated rate, filtering from 0.5 m.g.a.d. rate to the maximum of 6 m.g.a.d. With the author's plan the units would, after cleaning, be immediately started and continued at a high rate, being limited only to the size of piping.

Second: Referring to "reverse flow" there may have been an unintentional approach to this at one of the Philadelphia plants during a winter season when the thickness of ice forced the operation of the filters into unusual measures. The beds were dead due to service and close to 8 inches of ice had formed on the water surface. The beds were drained below sand permitting the ice to rest on the sand. Backfilling was applied and the ice lifted after which the units gave a length of run to permit the removal of a certain amount of ice. There might be a question whether this approached the reverse flow theory or whether the general clogging influences were not adhering to the under surface of the ice and freedom was given for the cleaner sand to function. With a properly designed pipe and under-

drain system, there should be a softening effect of a back wash carrying the finer sand for a new imposed removal layer. To obtain a uniform wash over a bed approaching an acre in size would require careful design and equally careful construction.

Third: The filter washer. Two units of the Blaisdell crane type washer have been in use for years in Philadelphia. The latter installation continues to function on beds of the scrubbing type and its service has been satisfactory. At time of writing the Blaisdell Company is under contract to furnish several filter washing machines embodying the principles described by the author. The design provides a gasolene driven caterpillar tread machine which travels over the submerged sand and experimental work during periods of study have indicated that higher rates may be maintained, reduction of "out of service" periods and economy on sand cleaning effected.

JOHN R. BAYLIS:[4] The article by Mr. Blaisdell on "Rapid Fine Sand Filtration" describes a very interesting method of increasing the rate of filtration for what is commonly known as slow sand filters; that is, filtration when the water is not coagulated by the addition of chemicals. A rate of filtration several times that of customary practice for slow sand filters is used. The literature on filtration contains no accurate measurement of the turbidity of the filtered water, neither does Mr. Blaisdell give the exact turbidity of the filter effluent for rapid fine sand filters. Consequently true comparisons cannot be made. It may be found when accurate measurments are made that there is a slight difference and that such high rates as suggested cannot be maintained. It seems probable, however, that rates considerably in excess of the now customary slow sand rates can be maintained with equal results. The method of making a clogged filter porous by reversing the flow of water at a rate so low that the suspended matter which has been filtered out will not be stirred up may mark an advance in slow sand filtration.

The article brings prominently to our attention the lack of knowledge on how a filter bed filters. Is filtration merely the straining out of the suspended matter, or is it the lodgement of the particles by being wedged in the interstices between the sand grains? Do attractive forces play any part in filtration? It is likely that all three methods by which suspended matter may be removed are brought into play in many filter plants. As to which will be the

[4] Principal Sanitary Chemist, Montebello Filters, Baltimore, Md.

prevailing one depends upon conditions. A brief explanation may be desirable. Straining is when the suspended particles are too large to pass through the pores of the filtering medium. After a short period of service the actual filtering medium may be largely the suspended matter which has been filtered out. Removal by lodge-

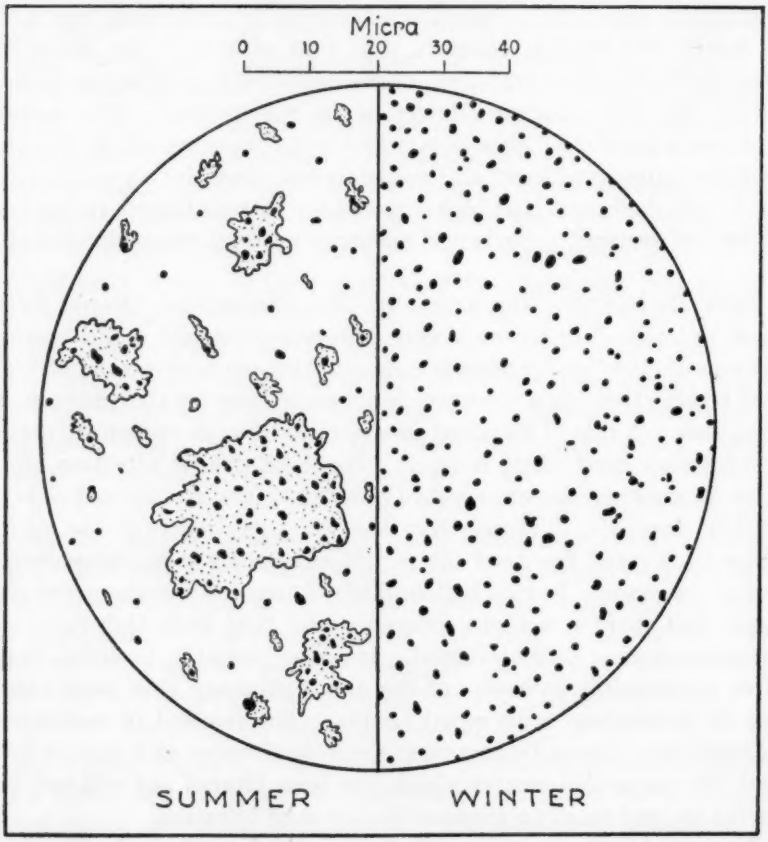


FIG. 11. EXTREME CHARACTERISTICS OF THE TURBIDITY OF THE RAW WATER AT BALTIMORE

ment probably can be best illustrated by assuming the filter bed greatly magnified. If the grains of sand were from 2 to 5 feet in diameter and the bed 400 to 500 feet deep, then the suspended particles would have to be from $\frac{1}{3}$ to over 1 inch in diameter to be on the same scale. If particles the size and shape of the enlarged

suspended particles were dropped on top of this pile of enlarged sand grains it is evident that very few would pass through. They would be wedged in the spaces where the sand grains touched. Attractive forces operate where there is a tendency for solids to be drawn together somewhat like the attraction of iron particles by a magnet. While not the prevailing factor in the removal of suspended matter, it is evident that part is removed in this manner.

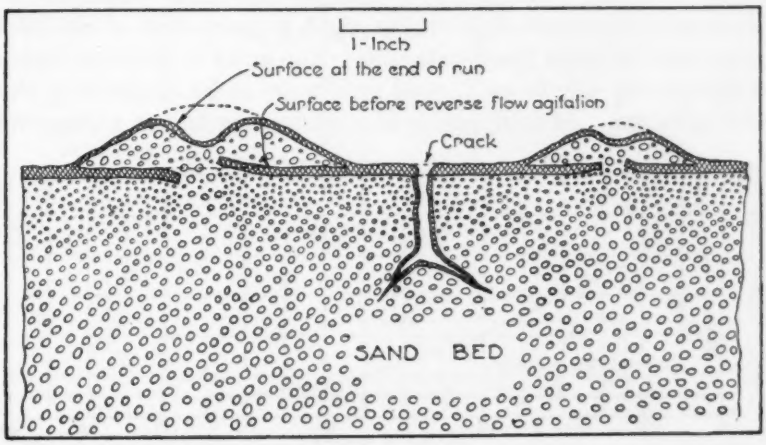


FIG. 12. CRACKS AND MOUNDS PRODUCED BY REVERSE FLOW AGITATION

When the filtration is nearly all in the surface of a filter bed a tough surface is soon formed, which causes the loss of head to rise rapidly. In such instances the beds may be agitated by reversing the flow to break the surface layer. The 24-inch wash water valves at the Montebello Filters, Baltimore Water Department, are opened 8 to 9 inches, let run for about one-fourth minute, and then closed. This breaks numerous holes through the surface and throws up small mounds of sand from 1 to about 10 inches in diameter. Slight cracks are also formed in other places, which soon open to larger cracks after the filters are in service a short while. Such a procedure frequently lengthens the filter run between washings nearly 100 per cent. Note the coarser sand grains thrown to the surface in the mounds.

Character of suspended matter quite variable. There is considerable difference in the character of the suspended matter in various waters. Figure 11 shows extreme conditions in the Baltimore raw water. The coarser particles shown on the left half of the camera lucida drawing are somewhat typical of size of particles at times. These particles are really nothing more than a partially coagulated water.

Such conditions usually occur in the warmer months, and is at least partially due to the production of organic jellies by biological growths. Most of the finer particles have been entrapped in the jelly or gelatinous precipitate. The right hand side of the drawing represents extreme dispersion of the suspended particles which sometimes occurs in the winter months. The water is between these extremes most of the time. The suspended matter in some water supplies may approach that shown on the left all the time, whereas others may approach that on the right a great deal of the time. Somewhere between these extremes is the point of fineness beyond which it is not safe to go, if good results are to be obtained by slow sand filtration. At such plants it is customary to use a coagulant

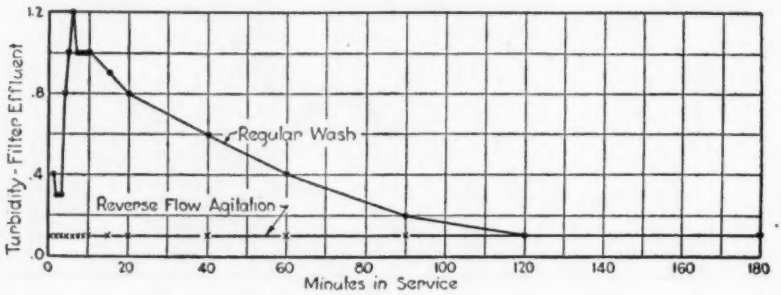


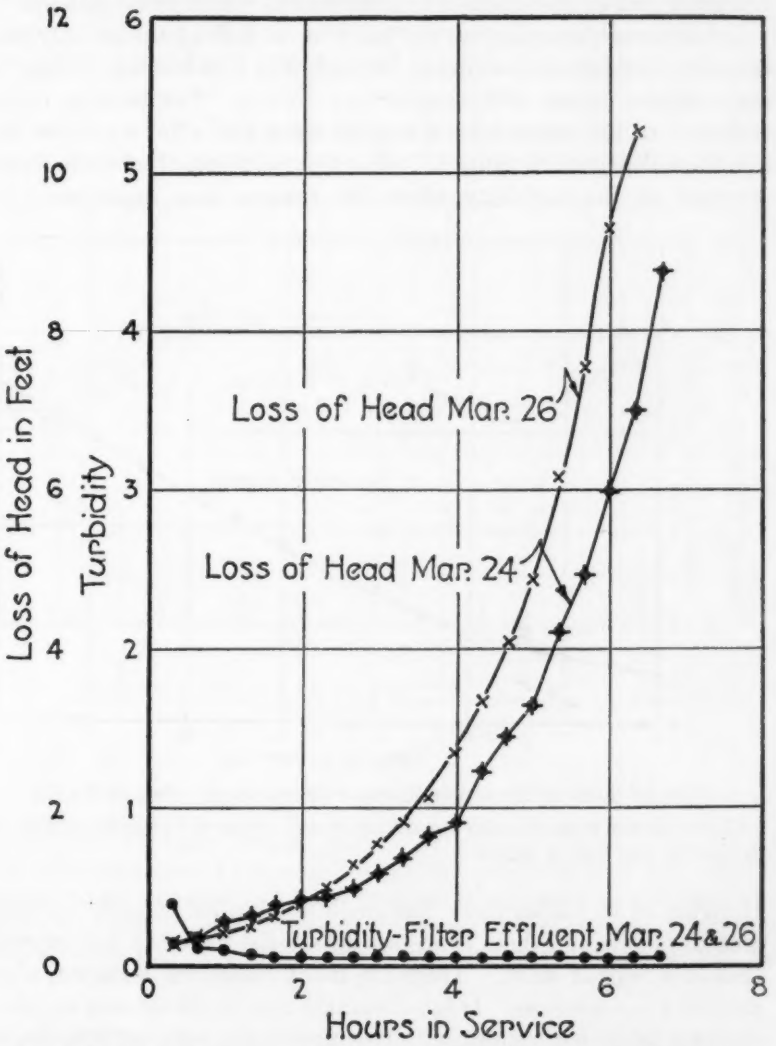
FIG. 13. COMPARISON OF THE TURBIDITY OF THE FILTER EFFLUENT AFTER A REGULAR WASH AND AFTER A REVERSE FLOW AGITATION. FILTER NO. 29

when the fineness exceeds the point where a clear filter effluent cannot be obtained. It may be possible that with the use of finer sand the limit of fineness beyond which the customary slow sand filter will not handle may be greatly extended.

What Mr. Blaisdell has done apparently has been to decrease the size of the pores through the sand bed and increase the rate of filtration. The result is an effluent approximately as satisfactory as that now being produced by slow sand filters. Increasing the rate of filtration and decreasing the size of the pores of the filter bed, of course, materially increase the rate at which the loss of head rises. To overcome this he reverses the flow of water through the bed at a rate just enough to open fine channels through the clogged layer. No water is actually lost in this treatment of the beds.

Reverse flow agitation occasionally used at Baltimore. Mr. Arm-

strong has used a procedure somewhat similar on rapid sand filter beds at the Montebello Filters during the warmer months when the



[FIG. 14. LOSS OF HEAD AND TURBIDITY OF FILTER EFFLUENT WHEN THE FILTRATION IS LARGELY IN THE SURFACE LAYER

loss of head increased rapidly. In this case there is an actual disturbance of the sand bed as shown in figure 12. The surface layer

is not only broken, but small mounds of sand are thrown up. If properly done, a fresh surface nearly equal to the area of the original bed is formed by the mounds and the cracks which soon open up.

It has been customary to use the reverse flow agitation only once between washings at Baltimore, though it is possible that it may be used several times with satisfactory results. Comparison of the turbidity of the water after a regular wash and after a reverse flow agitation is shown in figure 13. For this particular test there was no increase in the turbidity after the reverse flow agitation. Mr.

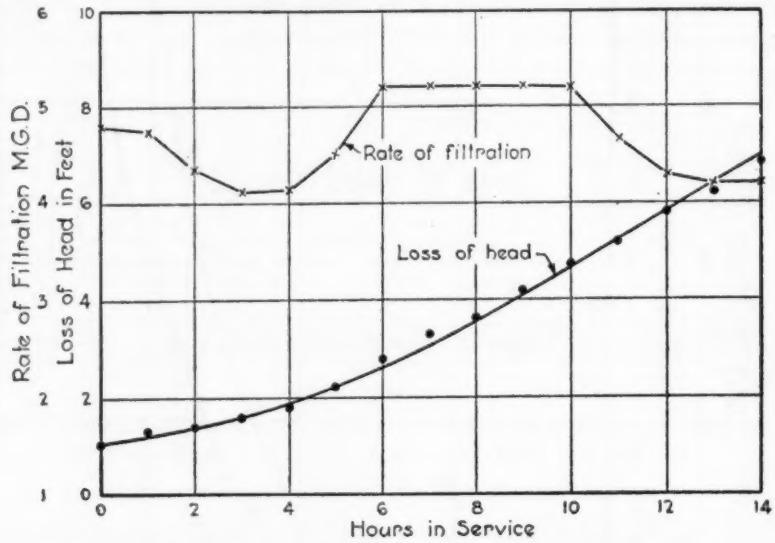


FIG. 15. LOSS OF HEAD AND RATE OF FILTRATION. FILTER NO. 10

Curves taken from circular recording chart. Note the increase in the rate of rise for the loss of head.

Hopkins of our laboratory has made a number of such turbidity measurements and there is no case where the turbidity has exceeded that of a regular wash. There are many instances, however, where there is some increase. It is our opinion that the filter runs are about doubled by such a procedure. This procedure, with varying degrees of agitation, is followed in many rapid sand filter plants at times when the filter runs are very short. Our experience indicates it to be good practice at certain seasons of the year, but it probably would not be for the major portion of the time. *It is good practice only when most of the filtration is in the surface layer.* Rapid fine sand filtration

apparently is the use of sand fine enough so that most of the filtration is in the surface, even though the suspended particles have not been coagulated by the addition of chemicals. As the surface layer becomes clogged pores are opened through it to sand deeper in the bed. The present procedure for slow sand filters is to scrape or rake the surface. The reverse flow may be applied with profit to some of the existing slow sand filter plants by increasing the time

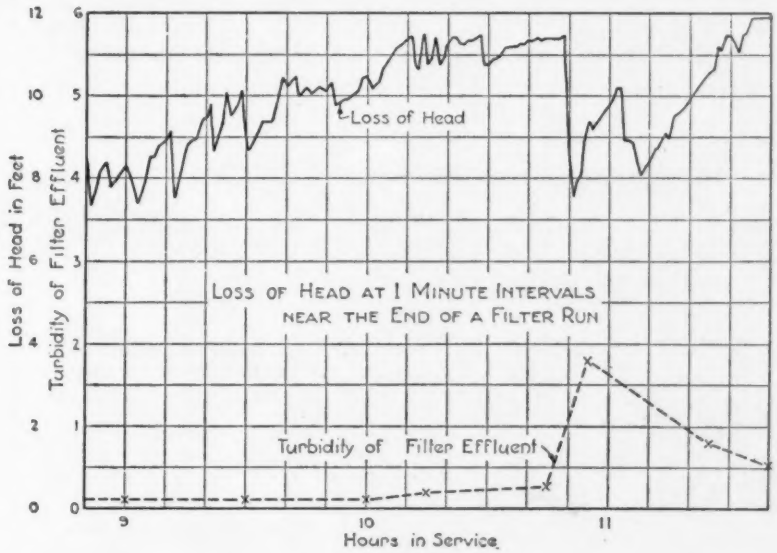


FIG. 16

This shows the loss of head was surging due to holes being forced through the surface layer of filtered coagulated matter, and to the formation of channels through the sand. The surging started at a loss of head of about 4 feet and was surging over 1 foot when the loss of head was about 5 feet. Due to increasing the rate of filtration and frictional resistances when a break occurs in so small a filter ($\frac{3}{4}$-inch diameter) the curve is not exactly typical of what happens in a large filter bed. There is probably a much greater surge at the point of break in a large bed.

between scrapings. Especially might it be applied at plants where the consumption of water requires maximum filtration rates, for it offers the possibility of increasing the rate without detriment to the quality of the water.

How suspended matter is removed by filtration. Perhaps a brief explanation of how filtration takes place in the ordinary rapid sand filter bed will give a clearer idea of what happens in rapid fine sand

filtration. We might say that rapid fine sand filtration is, to a certain extent, the reduction of all factors entering into the process of rapid coarse sand filtration. The particles of suspended matter are smaller, the pores through the sand bed are smaller, and the rate of filtration is lower. The filter beds, however, are not hydraulically graded, but Mr. Blaisdell claims there is some advantage in washing just a little of the fine sand to the surface.

If the removal of suspended matter is largely in the surface layer the loss of head will rise at an increasing rate somewhat as shown in figure 14. These curves are from an experimental laboratory filter, but the curve in figure 15 is from actual plant conditions when most

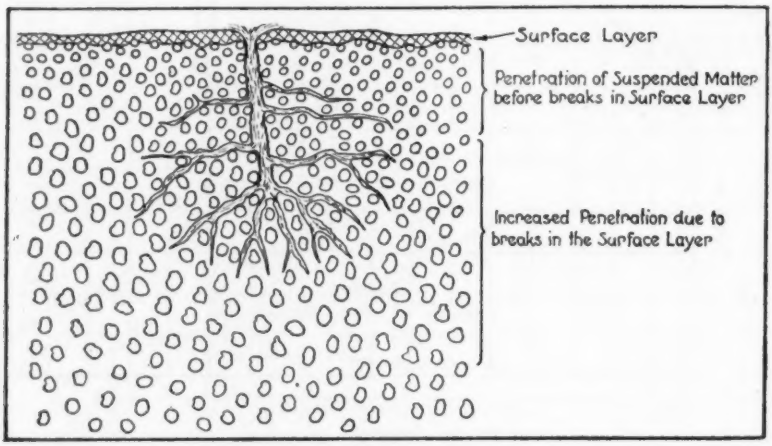

Surface Layer
Penetration of Suspended Matter before breaks in Surface Layer
Increased Penetration due to breaks in the Surface Layer

FIG. 17. PENETRATION OF SUSPENDED MATTER INTO A RAPID SAND FILTER BED

of the suspended matter was being removed in the surface layer. There is always some penetration of suspended matter into the beds under plant conditions and the curve does not increase in the rate of rise so rapidly as for the experimental filter where practically all filtration was in the surface layer. The increase in the rate of the rise of the loss of head is due to the suspended matter forming a compact film on the surface of the sand. Under most conditions the film does not build up tough enough to give a very high loss of head before it breaks. When breaks occur channels are formed in the upper layer of the sand, which tend to branch into smaller channels somewhat like the roots of a tree. At a depth of from $\frac{1}{2}$ to $1\frac{1}{2}$ inches the channels have branched so widely that the flow is only slightly in excess of the customary rate.

Immediately after the break the loss of head through the surface layer at the break has to be taken up by friction through the sand. Figure 16 shows the fluctuations in loss of head for a small $\frac{3}{4}$ inch laboratory sand filter after the head has reached a point where the suspended matter is being pulled below the surface of the sand. Should the difference in head through the surface layer be about 4 feet, it is readily seen that the water will rush through the break quite rapidly. Due to the limited area of the opening and the spreading of the water after it gets below the clogged layer, approximately normal rate of flow is reached in a very short distance. When the rate has slowed up to nearly normal, filtration begins to take place. This is illustrated in figure 17. The penetration of suspended matter into most of the sand beds, except where very coarse sand is used, is in this manner. There may be times in most plants when the water is cold, in which case most of the suspended matter penetrates into the beds and the filtration is largely by lodgement in the interstices of the sand and by attractive forces rather than by straining, but the prevailing manner is shown in figure 17.

In rapid fine sand filtration there is the same tendency, but due to most of the particles being much finer in proportion to the size of the pores through the bed, breaks, where there is considerable loss of head through the filtering layer, may result in some of the suspended matter passing the bed. It is largely for this reason that the rate of filtration has been made low for water which has not been coagulated. The reverse flow avoids sudden breaks in spots by opening up a large number of channels or pores over the entire bed. Then the loss of head is taken up by the control valve of the filter.

It seems that the method of filtration described by Mr. Blaisdell should be given careful consideration by those operating slow sand filters. Satisfactory drinking water should have the turbidity reduced to at least 0.5 parts per million. This is probably a lower figure than is being attained in many existing plants, but the trend is towards a clearer filter effluent and the merits of any new type of filter should be based on its ability to produce water which will meet this standard.

J. W. Ellms:[5] This paper describes the use of very fine sand in a filter bed of the general type used in slow sand filters. As the author

[5] Engineer of Water Purification and Sewage Disposal, Cleveland Water Department, Cleveland, Ohio.

advocates the use of reverse flow for the purpose of partial cleanings of the filter bed, he advises the installation of a carefully designed underdrain system capable of producing a uniform upward distribution of the wash water. For more thorough cleaning after prolonged periods of service, he uses his well known type of movable washer in which the sand is agitated by jets of water in a chamber lowered into the water and onto the sand surface to be cleaned. The dirty wash water is drawn off from the chamber and discharged into a wash water gutter provided for this purpose.

The efficiency of these filters lies, according to the author, in the very fine sand employed; i.e., sand with effective sizes ranging from 0.11 to 0.22 mm., and with uniformity coefficients varying from 1.5 to 3.9. As he claims that the efficiency of this type of filter is not related to the formation of a natural colloidal coating, created by bacterial action on the organic matter carried by the water, it would have been well to have shown the bacterial removals, or better the residual numbers of bacteria remaining in the effluent for a period of operation beginning with the starting of the filter containing the new clean sand and continuing for a period of five or six weeks. The usual type of slow sand filters and even rapid sand filters require a certain amount of "ripening" of the sand to produce the highest bacterial removals. It, therefore, is somewhat surprising that the author has found by merely decreasing the size of the sand that he is able to offset the efficiencies derived from a "ripened sand."

The relatively high rates of filtration employed and the losses of head resulting, even where turbid waters were filtered, are of considerable interest as indicating the possibility of using this type of filter on those natural waters which have generally been supposed as being more economically and efficiently purified by rapid sand filters using coagulants. It should be pointed out, however, that turbidities of filtrates ranging from 1 to 4 p.p.m. would not be acceptable to consumers who had ever been accustomed to a water entirely free from turbidity. The periodic "breaking" of the filter bed by reversal of flow, even though this is done at very low rates of rise of the wash water, is likely to produce slightly turbid effluents following the "breaking" operation. The more turbid the water being filtered is, the more likely the effluent will be slightly turbid.

The author states that these filters are very flexible, permitting the sudden increase in rates without impairing their efficiency. It has usually been considered that sudden changes in rates of filtration.

were likely to prove harmful, and should be avoided. However, with the filter bed composed of very fine sand, it may be that fluctuations in the rate of filtration within the ranges stated can be practiced without danger to the quality of the effluent. Detailed data on this point would be of interest.

The influence of entrained air on the loss of head in any type of filter bed is well recognized. In consequence, when starting a sand filter, it is customary to fill the bed slowly from the bottom in order that air may be driven out with the rising water. Any reversal of flow used by the author, after the filter has been operated for any period, would also effect the removal of air which may have accumulated in the bed. Air entrained near the sand surface would also be easily removed if the author's washing machine is employed.

The author attributes the high filtration rates which he employs, as compared with the rates generally used in operating slow sand filters, to the facility with which he can remove the entrained air from the bed. This explanation hardly seems necessary, since the use of higher rates of flow in the ordinary type of slow sand filter has not been prevented by an inherent difficulty in the passage of the water through the bed at greater velocities, but because these higher velocities produced poor grade effluents.

More detailed results of the operation of filters of the type advocated by the author will be welcomed by all those interested in water purification. There are undoubtedly some cases where the filtration of water without pre-treatment with a chemical coagulant, may be required, but it is not believed that such instances are at all frequent, or that in general the cost of such installations would be cheaper than a rapid sand filter plant of equal capacity. The writer cannot believe that there ever was or is ever likely to be a water purification plant either large or small, that does not require technical supervision. If the author has achieved this high degree of perfection in the operation of even small plants, the writer is open to conviction.

ALLEN HAZEN:[6] This paper gives emphasis to the straining action of fine sand. Very fine sand acts like a Pasteur filter and practically removes from passing water all bacteria and other solid matters of corresponding size. This was known definitely at Lawrence from experiments made thirty years ago, as well as from many other experiences.

[6] Consulting Engineer, New York, N. Y.

With coarser sands the straining ability varies inversely with the grain size. The use of sand fine enough to act as an effective strainer for any small particles is certainly advantageous in filtration.

The advantages of fine sand have perhaps been often lost sight of in connection with chemical treatment and coagulation, used as preliminary processes, which, under favorable conditions, have permitted water of the desired quality to be obtained with only the moderate straining to be obtained with coarse sand. But as a broad proposition the fine sand will frequently accomplish what the coarse sand cannot. Considered in this way fine sand is always desirable.

The disadvantage of fine sand has been the difficulty and expense of operating with it. Partly because of its greater straining power and partly because of its greater frictional resistance the runs to be obtained with it are shorter and more washing must be done. This is true both of mechanical filters and of sand filters. These conditions have practically led to the selection of sands coarse enough to permit reasonable economical washing and operation, even though there was a sacrifice in efficiency.

Mr. Blaisdell has used his great ingenuity and skill in devising a means of washing fine sand in place in a filter in such a way as to make its use in filters more feasible and practicable. The demonstration of the results to be obtained in this way, surprising as they seem, are really but repetition of what was found in the early work at Lawrence, as Mr. Blaisdell points out.

It would seem that there might well be an increased use of fine sand in meeting American water purification problems.

On the other hand, it must not be overlooked that, even with Mr. Blaisdell's most ingenious devices, there remain practical problems that must be met and above all, it must always be remembered that a factor of safety to cover unusual conditions must be maintained.

Tests show that a certain rate of filtration under full control will produce sudden results, but in the actual operation of a plant other conditions than those met in the tests must be anticipated and, as a matter of practical experience, to insure that a plant will function year in and year out with full efficiency, it is essential that conservative allowances for rate and other matters be made.

The paper is thus to be recommended as bringing again emphatically to our attention the advantages in the use of fine sand, and it is certainly worth our while to strive for these advantages as far as they can be secured without sacrificing other operating conditions.

APPLYING CEMENT LINING BY CENTRIFUGAL MEANS TO CAST IRON AND STEEL PIPES

By Donald Moir[1]

Early in the year 1923, the Directors of the Consolidated Water Works Company of Rosario de Santa Fé, Argentine Republic, in view of the trouble experienced from corrosion and tuberculation of their distribution system, decided that all extensions and renewals should in the future be laid with cement-lined pipe, the lining to be applied centrifugally with the object of assuring both its impermeability and its rigid adhesion to the metal.

Because of the limited number of manufacturers then in a position to supply centrifugally cement-lined pipe, full advantage could not be taken of trade competition to purchase pipes under the most favourable conditions. Furthermore, the extra freight charges on the weight of the lining combined to raise the price of these pipes considerably above that of the unlined variety.

It became evident, therefore, that, if a convenient process could be devised, whereby lining operations could be carried out on the spot by the Company, the extra freight charges mentioned would be eliminated and purchases of the unlined pipes could be made in the open market.

Essential features of any such process had of necessity to be: (1) low capital cost of the installation; (2) adaptability to a wide range of pipe diameters, and (3) economical results. The process ultimately decided upon, and developed, consists of applying to a pipe, into which has previously been introduced a measured quantity of semi-liquid cement mortar, a rotary motion by rolling down a suitable incline under the action of gravity, and of utilising the centrifugal force thus generated to project and consolidate around the interior of the pipe wall a uniform layer of the cement mortar referred to.

In actual practice at Rosario, two sets of parallel rails are laid on

[1] La Compania Consolidada de Aguas Corrientes Del Rosario, Rosario de Santa Fé, Argentine Republic, South America.

sleepers placed on the ground. Two of these rails are spaced at 9-foot gauge, and are utilised for coating pipes of the smaller sizes rolling upon their own circumference. The other two rails are spaced at 14-foot gauge, and deal with larger diameter pipes rolling upon end trunions of smaller diameter than that of the pipe.

It will be observed from the accompanying profile sketch in figure 1 that the track is made up of 3 sections of different grades. The first section "a b" is arranged, with respect to length and slope, so that a pipe starting from "a," and rolling to "b" will, upon reaching the latter point, have acquired a predetermined rate of rotation, while the grade of the second section "b c" maintains approximately constant this rate of rotation between "b" and "c." The upward inclined section "c d" simply acts as a brake and brings the pipe again to rest.

FIG. 1

A pipe placed at the point "a" possesses with relation to the point "b" a potential energy equivalent to WH foot pounds, where W = the weight of the pipe in pounds, and H = vertical height in feet between "a" and "b."

Upon rolling down to "b" this potential energy becomes converted, after deducting that spent in overcoming friction and windage, into what may be termed directional energy and rotative energy. It can easily be shown that in the case of a pipe rolling on its own circumference the value of the rotative energy is in all cases somewhat less than that of the directional energy. As only the former is of value in generating the centrifugal force required to effect the lining operation, it is desirable to increase the rotative energy at the expense of the directional energy. This can be accomplished in an exceedingly simple manner by providing rolling members of small diameter which may take the form of a steel tube passed through the pipe and projecting at each end a sufficient distance to rest and roll upon the rail track, the pipe being supported concentric with the tube by means of suitable end flanges attached to the latter. By this arrangement, a track which is only of sufficient length for lining small size pipes rolling upon their own circumference, can likewise be utilised for comparatively large diameters.

The pipes to be coated are placed on the horizontal at the top of the slope "a b." Here suitable end stoppers are fitted on; a measured quantity of semi-liquid cement mortar is poured in from either end through holes provided for the purpose in these stoppers; directional members in the form of taper cones are placed on the body of the pipe, if of small diameter, or on the end trunions, if of large diameter, with the object of correcting any tendency to derail; and the whole is then rolled over the edge of the slope "a b."

Under the action of gravity the speed of the pipe accelerates on its journey from "a" to "b." Throughout the first few yards of rolling the rate of rotation is, however, insufficient to throw the mortar outwards, and this therefore remains on the underside of the

TABLE 1

Cast iron pipes lined with cement to January 31, 1926

DIAMETER	METERS LINEAL
inches	
4	52,782.84
6	10,738.66
8	2,300.02
9	208.00
10	3,244.00
12	3,615.48
15	4,282.20
20	2,291.16
24	589.26
30	2,382.66

pipe and becomes distributed in a layer of uniform depth along its length. As the speed increases, a point is reached where the mortar becomes projected by centrifugal force against the pipe wall, forming a layer perfectly concentric with the axis of the pipe, while further increase in speed causes the excess water to be displaced towards the interior by the solid constituents of the mortar, because of the higher specific gravity of the latter. By maintaining the maximum velocity from "b" to "c" further displacement of the water, with a corresponding consolidation of the mortar, is effected and, upon the pipe being brought to rest by the stopping incline "c d," the excess water is run off, leaving a compacted and impermeable layer of mortar, smooth in surface and firmly adhering to the metal of the pipe. The end stoppers and directional members, previously referred to,

are then removed and, after a period, the length of which depends upon climatic conditions, the pipe is rolled into a water bath where it remains at least 24 hours, for the purpose of avoiding a too rapid drying of the mortar.

The process is admirably adapted for the use of municipal or private water undertakings that may, for reasons of economy, desire to carry out lining operations on site, and for their own account. Not only are they thereby enabled to protect all new piping from the ravishes of corrosion, but, at the same time, old piping which has become inadequate because of reduction in diameter from tuberculation, can be taken up, cleaned, coated and relaid, thus restoring its initial carrying capacity and securing, at comparatively little cost, what is practically equivalent to a new pipe. This latter facility will be appreciated by those who have to deal with distribution systems in which, because of the nature of the water conveyed, the incrustation problem has assumed serious proportions.

The first cost of the installation is exceedingly low, especially where ground is available possessing natural contour features approximating to the grade required, while not the least of its advantages is the elimination of a source of power for operation.

Since its adoption by the Rosario Water Works Company in June 1924, the lengths of new and old piping of the various diameters stated in table 1 have been successfully treated. The average cost based on a unit of 1 inch diameter and 1 metre length has worked out at $0.067 argentine paper, including all charges with the exception of depreciation and interest on capital, which are so small as to be practically negligible.

Any desired thickness of lining can be applied, and the practice followed here has been a thickness of $\frac{1}{16}$-inch on 4-inch pipes, gradually increasing to $\frac{3}{8}$-inch on 30-inch pipes, the mixture employed being 1 part of cement and 1 part of clean sand.

No difficulties have been experienced with the lining breaking away when drilling and tapping the pipes to receive the ferrule of the house connections, and even when cutting the pipes with a cold set and sledge hammer, fracture of the lining is found to coincide with that of the metal.

Rosario draws its domestic supply from the river Parana, the waters of which, being soft and exceedingly aggressive, rapidly build up tuberculation in the mains, with the corresponding falling off in capacity. Samples of centrifugally cemént-lined pipe, which have

been removed for inspection after a period of service of 1½ years have, however, been found to be perfectly clean, while neither the lining nor the metal shows the slightest sign of being affected.

Without being unduly optimistic, therefore, the author believes that a means has been found whereby water authorities, at a trifling cost, can effectively protect their mains and distribution systems against attack by soft or aggressive waters, and, at the same time, assure that the initial capacity of these will be maintained by prohibiting the formation of tubercles.

The process is equally adaptable to the application of protective linings of materials other than cement, or cement and sand. Asphaltic compositions, when put on in this manner, are entirely free from the minute pin hole defects always present in dipped coatings, through which the water penetrates to carry on its attack on the metal. In cases where this class of lining is preferred, its application centrifugally removes the most serious objection to its use.

FINANCING WATERWORKS PROJECTS[1]

By C. N. Phillips[2]

It is my intention to discuss the financing of waterworks projects from the standpoint of several years experience as a dealer in municipal securities. Theoretically two methods of financing are open to a municipal corporation desiring either to construct a water system, purchase a water system, or make substantial improvements or extensions to a system it already owns. These two methods are the payment of the cost from current revenues or by borrowing on the credit of the municipality through the medium of long time municipal water bonds. Practically speaking, in almost every instance the capital expenditure required is too great to be paid out of current revenues and I shall, therefore, deal with the financing of such projects by the issuance of municipal water bonds.

Municipal corporations have authority to issue bonds only as such authority is specifically granted by statute. The laws of the various states outline in detail the necessary steps to be taken, usually specify the maximum rate of interest such bonds may bear and contain certain restrictions as to the maturity of the bonds, price at which they may be sold, etc. In the three states of Colorado, Wyoming and New Mexico, there is a very wide divergence so far as certain features of these laws are concerned. I shall not bore you with a detailed résumé of these laws, but shall endeavor to outline certain principles and methods of precedure which it seems to me should be followed out as nearly as may be under the legal restrictions imposed by these laws. In so doing, I will have occasion to mention some of the outstanding features of these laws which must be taken into consideration.

When a bond issue is contemplated the first thing, naturally, to be determined is the maximum amount of bonds to be authorized. So far as this is concerned, we have no legal restriction in any one of

[1] Presented at Conference of Water Superintendents, Rocky Mountain Section, February 23, 1926.

[2] Jas. H. Causey Co., Investment Bankers, Denver, Colorado.

these three states, as their constitutions specifically exempt waterworks bonds from the operation of debt limits imposed for other purposes. This is also the case in most of the states throughout the country. There is good sound reason for this, particularly in the West. A good water supply is, of course, the most important requisite to a community of any size and in the West it is often necessary for municipalities to incur, and rightly so, a heavy amount of indebtedness in order to secure an adequate water supply. There is another reason for exempting the water debt from the operation of a debt limit and that is the fact that the revenues from the operation of the plant should, in addition to operating and maintaining the system, contribute substantially to the amount of money required for principal and interest on outstanding bonds, which I shall refer to as debt service. Of course, there is this to be said, except in certain very small communities where it would be impossible to charge a sufficient rate for water to provide all of the necessary funds and it is consequently imperative to depend partly on taxation, the question of whether this money comes from water sales or taxation is principally one of policy and bookkeeping.

Therefore, as to the amount of indebtedness which may be incurred, a municipality is limited only by the amount the taxpayers are willing to authorize and its ability to sell its bonds. It seems to me that public officials contemplating a bond issue for water works owe it to the taxpayers of the community as a first step to obtain adequate and competent engineering advice as to the original cost of a project and also the operating cost after it has been constructed, so that the taxpayer can be fully informed and exercise a really intelligent decision when he goes to the polls to vote on a bond issue. The taxpayers are entitled to this information, because in the final analysis municipal water bonds are secured by the taxing power of the municipality and not by the earnings of the water system. An ample amount should be included because any municipality has authority to issue a less amount of bonds than have been voted if the entire amount is not needed.

Outside of the duty to the property owners, our New Mexico friends find it practically imperative to know how much they will need when they start, because in New Mexico a bond issue can be submitted at regular municipal elections which occur only every two years and so it is extremely important that sufficient funds be provided in advance to complete any project which is undertaken.

In Colorado municipal officials have much more lee-way. In fact municipal officials in Colorado are given more authority in this respect than in any other State with which I am familiar. When an election has once been held in a municipality in Colorado and the erection or purchase of a water plant has been authorized by the taxpayers, the city council or board of trustees has power and authority, without again going to the voters, to issue whatever amount of bonds may be necessary in their judgment, such action, of course, being subject to the referendum. Wyoming requires an election for each bond issue, but permits the calling of special election at any time for the submission of water bonds to the voters.

With the amount of bonds determined, the next step is to arrange what we call the "set-up" of the issue, meaning the maturity, provisions for payment, rate of interest, etc. Modern practice has demonstrated that there are recognized principles of sound finance which should be applied to municipal affairs as well as to private business as far as possible. I believe the greatest evil in arranging municipal bond issues has been the tendency to postpone for too great a period the payment of the debt. In the matter of the maturity of municipal bonds and the method in which they are paid there has been much progress. The best thought on the subject of municipal finance requires that the term of a bond issue shall not exceed the life of the improvement, so that the burden of the improvement will not have to be borne by people who do not enjoy its benefits. In some of the eastern states where new bond laws have been enacted in recent years, provision is made that the maximum life of the bonds shall not exceed the life of the improvement, such life to be determined in some cases by statute and in others by the certificate of an official such as the city engineer. In arranging the manner of paying these debts, we have come to appreciate the great advantage of the serial or installment bond, as opposed to the old sinking fund bond. In the case of a serial bond issue no sinking fund, with its attendant possible abuses, is necessary, as provision is made each year for the exact amount of bonds maturing that year. As the principal of a serial bond issue is paid the interest is reduced each year the full amount of such payment, whereas, if the same amount of money were credited to a sinking fund it could probably not be invested to draw as much interest as the bonds carry. There are two plans of serial payment, one is to arrange a bond issue to mature in substantially equal amounts through a given period of years. Under this plan

the heaviest charge for debt service comes at the start. The second is what we call the "level tax plan" where the amount of principal due is increased periodically as the interest is reduced.

Theoretically a correctly arranged municipal bond issue should be paid in serial installments starting at the time the bonds are issued or very shortly thereafter and continuing through a reasonable life of the improvement. The laws under which waterworks bonds are issued in the three states we are considering were all passed a number of years ago before much consideration or thought was being given to these principles and in operating under them we find ourselves rather seriously handicapped.

The Colorado law, for instance, requires a water bond issue to be paid off within 15 years, but does not permit any of the bonds to be due in less than 10 years and does not require any provision for a sinking fund during the first 10 years. The Wyoming law provides for bonds running 30 years, but optional at the end of 15 years. It does not require any provision for the payment during the first 15 years. The New Mexico statutes allow a maximum maturity of 50 years, requiring bonds to be optional after 20 years. This statute does permit a serial bond issue so that in New Mexico a bond issue can be arranged as to maturity in accordance with the above principles, but it is not compulsory to do so.

It can be readily seen that under all these laws there is a long period of the best usefulness of the water plant during which time a municipality is not required to make any provision for the payment of the debt. In Colorado, particularly, the maximum maturity of the original bond issue is so short that most waterworks issues are refunded at the end of ten or fifteen years and usually without any reduction in the amount of the issue. The Colorado refunding law, fortunately, contains the benefit of more modern experience and it is compulsory that refunding bonds be paid serially. It is to be hoped that these laws will be re-enacted in the near future to incorporate the benefits of present day experience and practice.

The rate of interest is best determined by authorizing, when the bonds are voted, the maximum rate allowed by law and then determining the most advantageous rate when the bonds are sold. The next step is the securing of adequate and competent legal advice.

Modern practice among bond dealers requires that all bond issues be approved as to legality by a firm or attorneys who are known as experts in this line. Either through the agency of bond houses or by

municipalities getting directly in communication with such bond attorneys, their services can be secured for a reasonable fee to direct the procedure for any bond issue. On this point I take the liberty of quoting from a recent editorial from the Bond Buyer, the leading municipal bond journal. Commenting on inquiries they receive as to the advisability of this service, they say:

> Invariably our advice is to have a recognized firm of bond attorneys not only write the approving opinion but also supervise the proceedings from the start. A municipal bond issue which does not carry with it the opinion of one of these recognized bond attorneys is not readily salable and, therefore, the municipal bond dealer must secure this opinion at his own expense, if the issuing municipality has not seen fit to arrange for it prior to the public offering of the issue.
>
> In view of this situation, it follows that dealers bidding competitively for a bond issue, if advertised as carrying the opinion of these recognized attorneys, which opinion is to be paid for by the issuing municipality, will, in effect, add the cost of the opinion to the price which they offer to pay for the bonds, since the payment of the attorney's fee by the municipality clearly relieves them of one of the usual expenses which is incurred in handling a bond issue.
>
> Aside from the simple question of the cost of the opinion it seems to us there are other advantages accruing to a municipality which arranges in advance of its bond offering for the favorable opinion of a municipal bond attorney.
>
> First, to have the proceedings leading up to an issue supervised by one of these bond legal experts virtually precludes the chance of making some technical error that might invalidate the issue and lead to repassage of ordinances and resubmission of an issue to the voters, readvertising of an offering of bonds or some other duplication of effort and expense.
>
> Secondly, when the prospective buyers of an issue are assured that the favorable opinion of a recognized municipal bond attorney has been arranged for in advance, the dealer is assured that upon the award of the issue to him there will be no unusual delay in delivery of the bonds resulting from technical legal difficulties. This is most important because the dealer must always consider the possibility of fluctuations in the bond market. Unless he can resell the bonds to his clients quickly, his risk of having the market turn against him is considerable and he must take all of this into consideration in estimating the margin of profit to which he is entitled in handling the bonds.

It will be readily apparent that, particularly in New Mexico, with one bond election possible only once in every two years, a legal error in connection with such an election would be very serious. To my personal knowledge several of the larger cities in all three of these states already employ expert bond advice whenever they contemplate the issuance of bonds.

All of the suggestions which I have made so far have had to do with steps to be taken prior to the voting or authorization of bonds. When the preparatory work has been done in this way, the sale is a comparatively simple matter. There are two methods of bond sale, namely: public and private. Technically speaking a public sale is a public opening of sealed bids received after advertisement. New Mexico is the only one of the three states requiring by law public advertisement of water bonds. Here notice must be published for thirty days in a New York paper, a Santa Fé paper and a local paper. In Colorado and Wyoming the method of sale is left to the discretion of the municipal officials. In these states very often the sale of the bonds and the securing of proper legal instruction and competent advice as to the set-up of an issue are obtained all in one operation by selling the bonds prior to and subject to the election or authorization. Ample competition is obtainable by a short notice sent to a few houses known to be interested. On the other hand, where greater publicity is desired either the bond attorneys or bond houses are ready and willing to give municipalities the benefit of their knowledge and experience in helping them to prepare correctly a proper set-up for a bond issue.

One of the most common provisions in municipal bond statutes throughout the country is, or more correctly was, a provision requiring the bonds to be sold at not less than par, evidently inserted to prevent municipal officials from making an unfavorable bargain, and it is not uncommon to find both a maximum rate of interest and a provision that bonds must be sold at par. This applies both in Wyoming and New Mexico and every now and then a combination of circumstances results in a given municipality not being able to obtain par for bonds carrying the maximum rate of interest. When this condition exists, it is necessary either to hold up the project or evade the law.

Municipalities, without exception, can obtain a cheaper net borrowing rate on their bonds if they will, when permitted by law, sell at a slight discount. This enables the bond house to buy the bonds at a price so that it in turn can sell them to the ultimate investor at par and almost without exception investors will accept a lower rate of interest at par in comparison with a somewhat higher rate when they have to pay a premium.

I have been endeavoring to emphasize that the really important steps of a bond issue are the preliminary steps which are often given

the least consideration. Give your taxpayers ample information upon which to vote intelligently; take advantage of the services of bond attorneys and the bond houses in getting the most scientific set-up, particularly as to maturity and obtain the best possible legal service. If you let these matters go until the bonds have been voted and are ready for sale, it is often too late to adopt suggestions which obtained earlier might have been of great benefit.

PRECISE TURBIDITY READINGS BY ELECTRICAL METHODS[1]

By Leroy H. Scott[2]

The machine is so designed as to read all turbidities of the raw influent water into the plant. One is able then with only a glance at the pointer to tell the exact condition of the raw water.

The machine depends upon its action by the variation of light on a photo-electric cell. This cell is so made that the resistance will vary in direct proportion as the square of the power of light thrown on it. The variant light is made by passing light through a column of water. As the turbidity changes the light on the cell will vary accordingly.

The machine consists of only four parts, an ordinary electric light, water tube, photo-electric cell and an extremely sensitive galvanometer. Both ends of the water tube are sealed with a convex lens, both focusing in the same direction, that is, the lower one focuses into the water tube and the upper one on to the plate of the photo-electric cell. Water is made to circulate in at the bottom of the tube, through the tube and out at the top, keeping it entirely full, due to the rise of the effluent. At the bottom of the tube, under the lower lens is placed the electric light. At the top is placed the photo-electric cell in a light-tight compartment, and so arranged that the light from the tube will focus on the plate of the cell. It will be seen then with this arrangement that, as the water gets slightly turbid, the intensity of the light on the cell will vary. This varies the resistance in the cell, and this variation is recorded directly on the galvanometer, which scale is calibrated to be read in turbidities.

Some idea of just how sensitive the cell is can be appreciated when it is found that with a change of 0.16 foot candle of light there is a change of 60 micro-amperes, or a deflection of fifteen on the scale reading. These cells are made so that there is very little lag in response and the resistance is constantly the same with the same variation in light.

[1]Presented before the Illinois Section meeting, March 25, 1926.

[2]Chemist-in-charge, Delaware Filtration Plant, Delaware, Ohio.

A machine to be used on the filter effluent water is under construction, and it will vary from this machine only in that as the water gets turbid, it will trip an amplifying relay, closing a circuit and sounding an alarm on the operators floor calling his attention to that filter. The relay is adjustable and can be set to sound the alarm with a change in turbidity hardly noticeable to the eye.

It was found in experimenting with this machine that, when the water tube is filled with clear water, the whole acts as a thick convex lense, thus concentrating the light on the cell more than when the tube is empty. If the filter should get air bound or for some reason is not filtering any water, the alarm will sound, in the same way as if the filter were in a dirty condition.

THE BUSINESS SIDE OF PRIVATE FIRE PROTECTION[1]

By Dow R. Gwinn[2]

Private fire protection is service of a special character, not enjoyed generally but by a comparatively small number. It is a valuable service and as stated by a supreme court, "a standing guard over property against the peril or destruction by fire." It is a readiness to serve proposition.

There should be no confusion between private and public fire protection. They are as distinct as public police protection and private watchmen service.

A manufacturer who wants additional police or watchman service other than that which is furnished and paid for from public funds hires and pays for such watchmen as he needs or wants. A city would have no right to pay from public funds, except in case of an unusual emergency, for the services of a watchman on privately owned premises.

And on the same principle, a manufacturer who desires fire protection for his private property in addition to that which is enjoyed by the public in general, a service which gives him more than his neighbor is provided with, should pay for that service. The manufacturer should pay for special private fire service as he pays for special watchman or private police service.

Each class of consumers should pay its share of the cost of providing water service, and the small or domestic consumer has a right to complain where only a nominal charge is made for large connections for private fire protection.

It might be said that large connections for automatic sprinkler service do not cost the municipality anything, as the manufacturer pays for the inside pipes and equipment.

The National Board of Fire Underwriters, in their report of the Fire Prevention Committee (1911) on the City of Terre Haute, Indiana, under the head of "Protection," stated, "Reasonable protection for

[1] Presented before the Louisville Convention, April 28, 1925.

[2] Terre Haute, Indiana.

the principal mercantile district requires a fire flow in excess of maximum consumption of 6500 gallons per minute, with a system capable of delivering this amount about any block and hydrants so located as to deliver two-thirds of the quantity upon any large fire through nose lines, none exceeding 500 feet in length. The total quantity includes an allowance for losses from broken services, elevator and sprinkler connections incidental to a large fire and should be available at pressures sufficient to give direct hydrant streams."

Reports on other cities have also contained similar requirements. Now, if a water works plant, owned either by a municipality, or a company, having equipment sufficient for ordinary demands and fires, is required to have larger mains and other equipment to provide for service for automatic sprinklers, including the bleeding of mains when a large connection is broken, due to the falling of walls when the sprinklers fail to extinguish the fire, *why* should not such service through large connections be paid for by those who enjoy this unusual and valuable service with consequent saving in insurance premiums?

Let those who enjoy unusual and special service pay for it, if furnished at all.

Personally, the writer questions if such service should be furnished by means of large connections to public water mains. First: According to report of Committee on Private Fire Protection, (see Journal American Water Works Association, November, 1919) public water supplies in over a dozen cities have been polluted from independent fire service supplies through private fire service connections. Among the list are the cities of Lowell, Mass., Rockford, Ill., and Elgin, Ill. In the latter city an epidemic of typhoid, attributed to a dual private fire system, resulted in 18 deaths. An epidemic of typhoid in Logansport, Ind., 1924, was blamed on a dual connection between the City supply and that of a Railroad Company, resulting in 22 deaths. After this occurrence the Indiana State Board of Health issued an order prohibiting cross connections between city supplies and independent plants where the source of such independent supply was surface water.

Second: The danger of bleeding of public water supplies where the automatic sprinklers fail to extinguish a fire and the pipes are broken when the walls fall allowing enormous quantities of water to run to waste. It is almost impossible for an average direct pumping plant to maintain proper pressure and supply when, in addition to the ordinary demands for domestic consumption and uses by the fire

department at a large fire, a 4 or 6 inch connection is discharging at full capacity into the air. See report in Journal American Water Works Association November, 1919, of 15 cases of bleeding of water mains due to broken fire service connections.

Large connections for automatic sprinklers are a menace to the general or public fire protection. The writer is of the opinion that the time is coming when the Underwriters will be opposed to such connections for that reason. Perhaps the most serious case on record of the bleeding of water mains due to broken sprinkler connections was the Salem, Mass., conflagration in 1914. (See the Eng. News, Oct. 22, 1914, page 830, and Nov. 19, 1914, page 1035.)

F. A. McInnes and Clarence Goldsmith, then of the Boston Water Department, were present and furnished the report. To quote from this report:

> The two buildings (Chas. H. Keefe Plant and Carr Leather Co. plant) ignited immediately and a large number of sprinkler leads opened in a very short time, but were powerless to check the fire. The collapse of the buildings resulted in the breaking of the sprinkler pipes, allowing the capacity of the three large connections to be wasted from the 20-inch main. . . . .
>
> The lesson to be learned from the experience in Salem is that the existence of connections from a distribution system of such size that their failure destroys the pressure at the hydrant is a mistake that surely invites disaster to water works systems and doubly so on depending upon hydrant hose streams.
>
> The record of fires occurring in sprinkler risks during the past sixteen years shows that in a total of 14,253 fires, 13,691 were controlled by the opening of less than 51 sprinklers and only 662 or 4.6 per cent were not controlled by this number of sprinklers, which number can be supplied by a 4-inch connection.
>
> We are absolutely of the opinion that the flow of water through the connections to the Keefe and Carr plants practically destroyed the efficiency of the Salem Water Works system and are convinced that the size of such connections should be carefully restricted.

Evidence such as this is most convincing, especially as it is from two engineers of such high standing in the water works field.

Perhaps it would be the part of wisdom of water works superintendents to ask themselves if they are inviting a conflagration like the Salem one, or a typhoid epidemic like the one at Elgin, Ill., or Lowell, Mass.

In the proceedings of the Indiana Sanitary and Water Supply Association for 1916, page 104, W. S. Cramer, Chief Engineer of the Lexington, Ky., Water Works, and past President of this Association, is quoted as follows:

I cannot see any reason why any water works official should sanction any connection with a water system from any other source of supply. It is not a question of a check valve, or a dozen check valves, and it does not make any difference how many check valves you have, you still have the possibility and the hazard of pitting a human life against the saving of a few dollars, and it seems to me it is an outrageous proposition. I do not think the water works men ought to allow any connection of their water mains with any other source of supply.

On page 105 of the same proceedings Dr. W. F. King, now Secretary of the Indiana State Board of Health is quoted, as follows:

I think Mr. Cramer has struck the meat in the cocoanut. I have heard check valves discussed and various sorts of makeshifts or contraptions so to speak, to protect the water supply from an auxiliary water supply. It seems to me that the only reasonable and safe way to handle the proposition is to absolutely have a water supply that is intended for human consumption separate and distinct from any other source of supply. We have had several instances of that sort in this State (Indiana), one at Shelbyville a few years ago. The result always goes to prove that there is no absolute safety unless the water supply intended for human consumption is separate and distinct from any other source of supply.

It is not necessary in every case to have connections with a public water works for automatic sprinklers. The protection may be provided by independent or local equipment such as a cistern, fire pumps and elevated tanks. There is in Terre Haute a large wholesale grocery concern with several large buildings, one being seven stories in height, that is equipped with automatic sprinklers which has no connection with the public water system. In that case they pay the actual cost of it, including interest on the investment, depreciation, repairs, taxes, fuel used in maintaining steam, extra labor in looking after the pumps, and also additional labor on Sundays and holidays, and at such times as the factory may be shut down. An insurance expert estimated the cost of such private fire protection when furnished by the manufacturer, in one case to be approximately $600 per annum.

Why should large connections which are a menace to the health and general fire protection of a city be allowed? The writer would prefer not to assume the responsibility. However, if connections are allowed they should be restricted where the street mains are large enough to *four inches* in diameter, *should be metered through a fire-line meter and independent of all other supplies.* And *they should be paid for.*

The Indiana Public Service Commission in the Terre Haute Water Works Company case (1915) stated:

> There is no perceptible reason why the water company should be compelled to provide and maintain a sufficient supply of water to operate the water sprinklers in time of fire for private individuals without compensation. On the contrary, this special benefit to the property owner over and above what the municipal fire protection affords the people in common, should be paid by the private user.

The minimum meter rate should be based on the rated capacity of the fire meter in proportion to the minimum rate charged for small house meters and their rated capacity.

For instance, if the minimum monthly rate for house meters with a capacity of 15 gallons per minute is $1.00 and the fire meter has a capacity of 150 gallons per minute, then the minimum monthly rate for the latter should be ten times greater or $10.00 per month. However, the insurance interests would want a larger supply than 150 gallons per minute; if so, the rate should be in proportion, because the demands are greater, and a larger plant and equipment are necessary.

The savings due to automatic sprinklers in insurance premiums amount in some cases to $3000 per year. In one case where $300 per year was paid the water company for fire protection, there was an actual saving of $1120 per year after allowing for interest and also depreciation on equipment.

All the water department or company has to sell is water and fire protection service, hence automatic sprinkler service should be paid for. The payment by a city of public fire hydrant rental does not cover private fire protection service.

REFERENCES TO COURT DECISIONS CONCERNING PRIVATE FIRE PROTECTION

> The principal object of the defendant's water board in requiring fire service pipes to be metered is to prevent the surreptitious or careless withdrawal of water through such pipes for other purposes than the extinguishment of fires; another object is to procure the measurement by meter of all water consumed for any purpose in order to check wastage and to require each taker to pay for the exact quantity of water furnished by him.
>
> Both upon principle and authority we are of opinion that under circumstances like those before us it is not unreasonable to require the installation of a meter at the plaintiff's own expense in its private fire service pipes.
>
> Nor can it be said that this regulation imposes undue burden upon the plaintiff. The defendant has afforded reasonable means of extinguishing

fires by public hydrants; if the plaintiff desires in addition a private system for the protection of its own buildings, it is not unfair for the defendant to impose, as a condition of supplying without other charge, water to make this system available, the requirement that the plaintiff shall take this water only through a meter to be put in at the plaintiff's expense.—*Shaw Stocking Company v. City of Lowell (Supreme Judicial Court of Massachusetts; Middlesex. May 22nd, 1908. 85 Northeastern Reporter, 90).*

The proprietor of a building, who installed therein an automatic sprinkler system, intending thereby to put out fires before they could gain headway, derives benefit for the system in fire protection and reduced insurance rates, and though there be a general benefit in reducing fire hazards, yet a municipal water works system to which the sprinkler is attached performs a service, and stands ready to perform others for which charges may be made.

It is evident that payment for the small quantity of water used would be wholly inadequate as compensation for the pressure required, and the readiness at all times to serve and the inspection of the city which might well be exacted.—*Edgerly vs. City of Ottawa, 156 N. W. 388, decided Feb. 1916, by the Supreme Court of Iowa.*

Action to restrain city from placing a meter on fire extinguishing plant dismissed by Appellate Division of the Supreme Court. Judgment affirmed with costs.—*American Mfg. Co., Appellant, vs. City of New York. Court of Appeals of N. Y. January 27, 1911.*

A water company which supplies the pressure and water for an automatic sprinkler for a private corporation performs a service which is not included under its contract with the city to supply water for fire protection and has the right to make a reasonable charge therefor against the corporation.—*D. B. Loveman Co. vs. City Water Co., 1 Tenn. Ch. App. 596.*

In the matter of furnishing water to its citizens, a city when authorized by its charter acts in a private rather than a governmental capacity and has the same right to make reasonable charges therefor that a private corporation has when serving the public.—*St. Louis Brewing Ass'n vs. City of St. Louis, 140 Mo. 419—37 S. W. 525, 41 S. W. 911.*

A rule, providing that water meters might be installed at the pleasure of the water board on the consumer and that after they had once been installed, the consumer could not thereafter return to the flat rate, is reasonable and may be enforced where the meter rates are reasonable and no discrimination between consumers is shown.—*Powell vs. Duluth 97 N. W. 450.*

The law imposes no duty to insure the property or extinguish fires.—*Woodberry vs. Tampa Water Co., 57 Fla. 243, 49 So. 556.*

The Arizona Commission in fixing rates to be paid to a water company, decided that a mining company desiring a private fire protection system, should be required to pay a fixed demand charge although "the actual water consumed for this purpose is likely to be negligible.—*Arizona Corp. Com. vs. Morenci Water Company, Public Utilities Reports, 1915, C 525, 527.*

A great deal has been written upon the subject of charges for private fire protection, such as service for inside private hydrants and sprinkler systems. It seems to be the consensus of opinion of operators that a minimum charge is entirely reasonable based on the idea of the "ready to serve" proposition. It is

obvious that a manufacturing establishment or other business installs such private fire service equipment for the special security of its own property over and above the protection undertaken by the water company for the benefit of the public. For this reason it might be equitable to assess some charge for this service varying with the size of the connection. In the present instance, it appears that the water utility will be justified in metering all services installed for the purpose of such protection, not with the idea of charging for water used in case of fire, but for protection against surreptitious use as close inspection and supervision have been found in many cases to be inadequate.—*Beloit, Wis., vs. Beloit Water, etc., Co., Public Utility Reports, 1915, B.p.1005, 1020.*

The benefit derived was not incidental, but it was the result of a direct appropriation by the furniture factory of power and water, which was the property of another, as a standing guard over its property against the peril or destruction by fire. Connection with a light or water plant accompanied by the asserted right of using it and the means of exercising the right is a benefit enjoyed at the hands of another imposing an obligation to make reasonable compensation although the occasion for actual use never arises. Here there was not only the connection, the asserted right to use it and the means of exercising the right affording continual protection against fire, but there was a positive saving of insurance bestowed upon the furniture factory by the water company. The fact that there was no use, no actual consumption of water, is a factor to be considered in estimating what should be the amount of compensation, but it does not relieve the furniture factory from liability for the fire protection furnished at the expense and labor of the water company.—*Cox v. Abbeville Furniture Co., 54 S. E. 830.*

So long as water supplied for protection against fire is a purely public service, under the control and management of municipal authorities generally, and under the fire department specificially, no direct charge to individuals is proper. When, however, a sprinkling connection is made with private premises the situation is materially different. These premises and the primary causes of catastrophe to the building and of the consequent possible use of disastrous quantities of water are primarily under the control, not of the public, but of the owner. A peculiar personal service is provided for his benefit, which is not enjoyed in common by the community in general, but is available only to a limited class of individuals. It does not advance the reasoning in this connection to split hairs between the "use" and the consumption of water. As a matter of good sense the property owner beneficially employs the water mains for his own purposes and to his own advantage, although he may not, except in case of fire, actually draw any water from the pipes. It is necessary and proper that for this he should pay. In effect he gets something of pecuniary value from another, which that other is not compelled to give except on the basis of contract. That the law required the terms of that contract to be reasonable and impartial or that advantage is mutual and involves no expense, is merely incidental or collateral. The conclusion is reached that a charge can be made. How great that charge should be in the view here taken is not before us.—*Gordon v. Doran, S. L. R. A. (N. S.) 1049. (The same case is reported in Ill., N. W. 272.)*

REACTION OF ORTHO-TOLIDINE WITH SURFACE WATERS

By Ole Forsberg[1]

The ortho-tolidine test for residual chlorine, because of its simplicity and rapidity, is a valuable aid, and in many instances the only method used, in controlling the chlorination of water supplies. In communities where chlorine sterilization is employed, and where facilities for regular bacteriological examinations are not available, the ortho-tolidine test is used to determine the efficiency of the treatment. Any physical or chemical property of the water which vitiates the reliability of the test seriously affects the quality of the water produced under these conditions.

The writer's attention was called to the discrepancy between the apparent and true ortho-tolidine reaction with chlorine, while investigating a water supply in July, 1922. The water was taken from a spring fed lake and pumped directly into the distribution system, being treated with chlorine at the pump intake. It had been determined that maintaining a residual of 0.08 to 0.10 p.p.m. free chlorine at a sampling point about two miles from the pump station produced a water of good sanitary quality. At the time of this investigation it was found that the untreated water gave a reaction with ortho-tolidine equivalent to 0.07 p.p.m. free chlorine. The water contained 0.4 p.p.m. Fe and 0.3 p.p.m. Mn, and filtering through "Whatman No. 44" filter paper removed 0.35 p.p.m. Fe and 0.2 p.p.m. Mn. The filtrate from the raw water did not react with the ortho-tolidine, while the residue on the paper gave a positive test. On filtering the chlorinated water the filtrate gave a definite reaction, but with increased dose the reaction was not proportionate to the chlorine introduced.

It was decided that the reaction of ortho-tolidine with the raw water was caused by the iron and manganese present, and in addition to the ortho-tolidine test, regular bacteriological examinations would be necessary to control the chlorine sterilization process.

[1]Bacteriologist, Oliver Iron Mining Company, Hibbing, Minn.

During the past 3 years thirty lakes, ten of which are used as sources for public water supplies, have been examined as to the reaction with ortho-tolidine. All but five, at one time or another, gave a reaction varying from a trace to 0.2 p.p.m. free chlorine. Sixty samples when taken did not give the reaction; about half of these reacted after standing in the laboratory, and only 27 of the 150 samples examined failed to produce a color with ortho-tolidine. When filtered through "Whatman No. 44" filter paper only eight of the 100 samples thus treated gave a color. The residue on the paper washed back into the filtrate gave approximately the same color as the original with ortho-tolidine. All samples giving a positive test contained iron and manganese.

When ortho-tolidine is added, drop by drop, to a water giving a positive test, the following color changes are often observed: blue, blue-green, and finally yellow. It was thought that this may be due to iron and manganese, but the same color changes occur with chlorinated water free from these elements, and, vary with the hydrogen-ion concentration of the solution. The first indication of green is noticed at a pH of 4.8, the full blue at 6.2, while at 6.4 a faint muddy color appears, which is not affected by further changes in the pH of the solution. These color changes were found only in water containing free chlorine or manganic compounds. Water, alcohol, and sulphuric acid solutions of ortho-tolidine give the same results as the standard ten per cent hydrochloric acid reagent. All pH determinations were made colorimetrically, and were subject to the errors introduced by the action of free chlorine on the indicators.

From a series of laboratory experiments, conducted for the purpose of observing the reaction of iron and manganese salts with ortho-tolidine, the following results were noted. Dilute solutions of ferrous and manganous salts, up to 10 p.p.m., do not react with ortho-tolidine. Solutions of ferric chloride do not react immediately with ortho-tolidine; but on standing develop a marked color. A solution containing 2 p.p.m. iron as ferric chloride, to which the usual amount of reagent, 1 cc. to 100, has been added, will, at the end of twenty minutes, develop a color equivalent to 0.03 p.p.m. free chlorine: on standing 90 minutes the color developed is equivalent to 0.10 p.p.m. free chlorine. For all practical purposes, ferric salts do not interfere with the accuracy of the ortho-tolidine test.

Water containing manganese as manganic hydroxides gives the same reaction with ortho-tolidine as chlorinated water, irrespective

of whether a water, alcohol, sulphuric acid, or hydrochloric acid solution of the reagent is used. The color changes produced, yellow, green, and blue, vary with the hydrogen-ion concentration of the solution as in water containing free chlorine. The ortho-tolidine reagent is very sensitive to water containing manganic hydroxides, 0.05 and 2.0 p.p.m. giving a color equivalent to 0.03 and 0.5 p.p.m. free chlorine, respectively.

A ground water with an alkalinity of 70 p.p.m. and a pH of 6.2, containing 0.4 p.p.m. Fe and 0.7 p.p.m. Mn was tested for its reaction with ortho-tolidine on numerous occasions. The water as drawn from a tap gives no reaction; boiling and cooling the water changes the pH to 7.6 and with ortho-tolidine produces a color equivalent to 0.15 p.p.m. free chlorine. Filtering through "Whatman No. 44" filter paper removes all the iron and 0.3 p.p.m. Mn. The filtrate does not react with ortho-tolidine.

Surface waters which give a color reaction with ortho-tolidine contain iron and manganese. The filtrate from these waters do not give the color reaction. Water containing only iron compounds, when these do not exceed 10 p.p.m., do not react with ortho-tolidine. Water containing even very small amounts of manganic hydroxides give the same reaction as those produced with free chlorine.

SOCIETY AFFAIRS

INDIANA SECTION

The Indiana Section met at Purdue University on March 25 and 26, 1926.

From the time the registration started until the close of the last session, the attendance was good.

There were a number of mayors, fire chiefs, and city engineers in attendance, taking part in the discussions and evidencing a desire to co-operate toward a more effective relationship between the water utilities, the various city departments, and the public.

Dean A. W. Potter of Purdue welcomed the Association and emphasized the desire of the university to establish a close contact with the water supply industry and to be of service in every way possible.

H. S. Morse responded thanking Dean Potter for his assistance and interest in the advancement of the art.

The development of the Boonville, Indiana, water supply was made imperative by a serious water shortage which the people of the town financed in order to avert a threatened water famine. The account of the very rapid construction was given by Charles Brossman, Consulting Engineer, who designed and built the new system.

Many fire chiefs enjoyed the paper presented by Percy Bugbee of the National Fire Protection Association and entered into the discussion. The general adoption of fire prevention ordinances controlling roofing materials, electrical installations, and general clean up was urged.

Mr. Zucrow, research assistant in the Purdue Hydraulics Laboratory, outlined the various methods of measuring liquids and demonstrated them under working conditions in the laboratory.

Beekman C. Little attended the dinner and spoke a few minutes. On account of illness, he was unable to attend all the sessions.

Following the dinner, a group of Purdue students entertained the Association with novel music and athletic events of a very high order.

Frank C. Jordan, past President of the Association, presided at the evening meeting, the program of which was broadcasted.

Dr. A. J. McLaughlin, Senior Surgeon of the United States Public

Health Service traced the development of public health measures from early times. Centuries before the development of the germ theory of disease, the danger of foul water was recognized and extensive works for the distribution of water and the collection of sewage were in use. The prosperity and development of the present day is possible in a large measure by virtue of the great advances made in disease control.

Fire Prevention in Indiana was the subject of an address by Clarence Goldsmith, Assistant Chief Engineer of the National Board of Fire Underwriters. Mr. Goldsmith asked for proper regulatory laws, but stressed the need for adequate and continuous inspection and the development in the public mind of a desire to avoid hazardous construction and the maintenance of bad conditions.

On Friday morning, Professor W. K. Hatt of Purdue traced the development of the concrete industry and detailed some of the new work which has made possible the accurate control of strength in the finished structure. He suggested that a contractor be permitted to use such mixes as he chooses to produce the strength required. If a wet mortar costs less to handle than the additional cement required, he should be permitted to use it provided the proper cement water ratio is maintained. This paper was discussed by J. W. Kelly of the Portland Cement Association and W. C. Mabee of the Indianapolis Water Company.

L. S. Finch, Director of the Water and Sewage Division of the Indiana State Board of Health, and H. A. Dill, Manager of the Richmond Water Company, reported some of the more serious water shortages in the state and insisted that many could be avoided by intelligent study of the distribution of the demand and the available supply using data developed over a period of years.

The Electrification of the Lafayette Water Works has resulted in a very substantial saving in operating costs. This work was reported by John W. Moore, Consulting Engineer, Indianapolis, who designed it.

W. C. Purdy of the United States Public Health Service was unable to be present, but his most enjoyable paper was read and discussed at length. An increasing interest is being shown in the evidence obtainable by a study of the plankton in our streams, and the pleasure and fascination of such a study are being realized.

The power end of the water works plant was very ably handled by Professor A. W. Cole of Purdue. Professor Cole called attention

to the very general disregard of the boiler equipment and emphasized the necessity for not only proper attention to operation and repair, but for modern efficient installations, saying that many times an old out-of-date boiler cost much more in operation than the interest on a new plant.

Every water works man is concerned in pipe laying and John W. Toyne, Consulting Engineer, South Bend, found an attentive audience for his discussion of Pipe Laying Methods. Mr. Toyne referred to the tendency to eliminate hand labor by the use of ditchers and back fillers. He ridiculed the idea of using new pipe lines prior to sterilization after exercising such care in the preparation of the water for consumption.

Every water supply organization hopes to avoid offering cause for complaint on the part of a customer. G. C. Staley of the Indianapolis Water Company outlined some of the means used to avoid mistakes and unfavorable impressions on the public. Common courtesy intelligently and consistently applied avoids many unpleasant situations.

E. A. Scott, Director of Public Relations, Interstate Public Service Commission, outlined the general modern policy governing the relation between utilities and the public, looking to a friendliness displacing the antagonistic attitude formerly often assumed by both.

This was one of the most successful meetings the Indiana Section has ever held. The attendance was large throughout the meeting. The papers were well prepared and on topics of wide interest. The facilities offered at Purdue University for such a gathering are splendid and our contact with the faculty most pleasant.

The following officers were elected to serve for one year.

President, H. S. Morse.

Vice-President, John W. Moore.

Secretary-Treasurer, C. K. Calvert.

Assistant Secretary, Lewis S. Finch.

Executive Committee: F. C. Jordan, W. L. Younce, W. C. Ridgeway, Howard Dill, W. H. Durbin, Charles Brossman, and I. L. Miller.

REPORT OF THE RESOLUTIONS COMMITTEE

(1) This Association wishes to express its appreciation for the courtesies that it has received from the Staff of Purdue University. We could not ask for more. Especially do we appreciate the way in which Professor W. A. Knapp has handled the local arrangements for this meeting. Preparation for

our meetings has never been better made. Our renewed acquaintance with the University strengthens our loyal support of it. The training that it gives to the students is of value to all public utilities as well as to the people at large.

We appreciate the cordial invitation to return for later meetings and recommend that this Association meet at Purdue University whenever possible.

(2) We are glad to have had the privilege of discussing fire prevention measures during this meeting. No more important topic can be discussed by our organization. To those actively in this work we renew our support. Indiana can well carry on the systematic community work in reducing fire losses. We pledge our full support to a constructive program of active fire prevention in Indiana.

(3) We view with pride the growth of the American Water Works Association. We believe that every wide awake man in public water supply work should be a member. He will find himself able to do better work by so doing. We especially urge the Mayors of Indiana to see that their water departments are represented in the membership of the Association.

(4) We wish to restate the object of this Association to be "the study of the sources of water supply in the State of Indiana, their conservation and purification."

It is our desire to insure to every citizen a safe, wholesome and adequate water supply, and to that end we ask the intelligent cooperation of the people of Indiana.

(5) We remember with thankful hearts the years of service given by Dr. John N. Hurty.

We believe that his successor, Dr. Wm. F. King, is carrying on the work in a way that is for the best interests of the state.

We heartily commend the action of the Indiana State Board of Health in regard to the pollution of the lakes of the state, and it is the desire of this Association that this action be extended to include all of the water courses of Indiana.

(6) A number of years have elapsed since the American Water Works Association has met in Chicago.

In 1927 several large projects are expected to be completed. It is felt that the National Association may be of assistance in hastening the construction of certain additional works to the improvement of the Chicago Water Supply.

We, therefore, direct the secretary to petition the Executive Board of the American Water Works Association to act favorably on the invitation from Chicago to hold the 46th Annual Convention in that city.

CENTRAL STATES SECTION

The Central States Section met in Erie, Pa. on October 9 and 10, 1925.

The Erie Convention was entertained by the Commissioners of Water Works in the City of Erie and others.

The Commissioners opened headquarters in the Lawrence Hotel and were at home to all of the delegates day and night, during the

two day period. There was an attendance of about 100 delegates, and meetings were well attended and the papers, with discussions, were good.

After the scheduled meetings on the first day the delegates were taken by automobile for a trip around the City, including an inspection of the manufacturing plant of the Hays Manufacturing Company, returning to the hotel where dinner was provided for all by the attending members of the Manufacturers Association. After the dinner the delegates were guests of the Hays Manufacturing Company at a theater party and this was followed by a reception at the home of Mr. Gensheimer, Secretary to the Water Commissioners.

At the end of the afternoon session on Saturday the delegates were again taken for an automobile trip over the new Seneca Highway of Presque Isle peninsula leading to Water Works Park. On returning from this trip the delegates were the guests of the Water Commissioners at a dinner served at one long table on the operating floor of the filtration plant.

At the end of the Saturday afternoon session the election of officers resulted as follows:

President, J. W. Ellms;

Vice-President, Chester F. Drake;

Trustees, Mentor Hetzer, D. C. Grobbel.

The Secretary-Treasurer is to be appointed by the newly elected officers.

The 1926 Convention is to be held at Cleveland at a date to be fixed by the incoming officers. The incoming officers were also authorized by the 1925 Convention to prepare rules and regulations for the activities of the Section.

The program follows:

FRIDAY, OCTOBER 9

Morning Session

9:00 a.m. Address by President Gensheimer.
Welcome by Mayor of the City of Erie.
Minutes of Last Meeting.

10:00 a.m. Address by the President of the American Water Works Association. H. F. Huy.

10:40 a.m. Address by the Secretary of the American Water Works Association. Beekman C. Little.

11:20 a.m. Installation of Meters in the City of Erie. D. W. Harper.

Afternoon Session

2:00 p.m. Water Supply and Sewage Disposal of Cities on the Great Lakes. J. W. Ellms.
3:00 p.m. Zeolite Softening Plant of the Ohio Valley Water Company. F. B. Beech.
3:30 p.m. Another Type of Dry Feed Machine. W. U. Gallagher.
4:00 p.m. Progress of Melcroft Coal Case. C. A. Emerson.

SATURDAY, OCTOBER 10

Morning Session

9:00 a.m. Office Administration of City Water Departments. D. C. Grobbel.
10:00 a.m. Council on Standardization led by J. N. Chester followed by Discussion of the new Manual of Water Works Practice.

Afternoon Session

2:00 p.m. Meter Maintenance Under Conditions of Hard Water. George Whysall.
2:40 p.m. Superintendents' Session.
4:00 p.m. Question Box.
Election of Officers and 1926 Convention City.

ILLINOIS SECTION

The eighteenth annual meeting of the Illinois Section of the American Water Works Association was held at the University of Illinois on March 24 and 25, 1926. This was one of the most successful meetings in recent years and the attendance of members of the Illinois Section was greater than for many years past. (An approximate check shows about same for 1916 and 1917.) The attendance included thirty-nine active members, representatives of three corporate members, and representatives of seven associate members of this section. The attendance of members from outside of the state was comparatively small. It included two active members and representatives of six associate members of the society. Several were prevented from attending by illness, previous engagements, and attendance at the Indiana section meeting.

Every paper listed on the program was presented and they were freely discussed. The talk by Beekman C. Little, Secretary of the Association, was on affairs of the Association and was very interesting and instructive.

The weather was exceptional and many availed themselves of the opportunity to see the experimental and demonstration apparatus

which had been explained at the meeting by Professors M. L. Enger and H. E. Babbitt; to accept the courtesy of Mr. Amsbary and visit the plant of the Champaign and Urbana Water Company; and to accept the courtesy of G. H. Radebaugh, manager of the Urbana-Champaign Sanitary District, and visit the sewage disposal plant of the district.

The following resolution was adopted:

WHEREAS the Illinois section of the American Water Works Association has suffered a loss in the death of G. A. Wadsworth, Superintendent of Water Works at Evanston, a valued member of this organization, who was killed by accident on October 1, 1925, while actively engaged in performing his official duties:

Therefore be it resolved that this society express its deep regret at the loss of this member and extend its profound sympathy to his family and further be it resolved that this resolution be spread on the minutes, and that copies be sent to the Mayor of Evanston, the members of his family, and the editor of the Association for publication in the Journal.

A resolution urging the executive committee to hold the 1927 annual meeting in Chicago was adopted unanimously. It follows:

WHEREAS, The City of Chicago through its Mayor, Commissioner of Public Works, and the Association of Commerce, has extended an invitation to the American Water Works Association to hold its 1927 convention in Chicago, and

WHEREAS, the Chicago water works, through the construction of the world's largest pumping station, which will be completed about the time of the 1927 convention, its tunnel construction, installation of meters at a rate of 40,000 meters per year, and other construction projects of both large and small magnitude, offer much of interest and educational advantages to the members of the A. W. W. A., and

WHEREAS, the passage by the City Council of Chicago in September of last year of a universal metering ordinance paves the way for the practical financing of needed filtration plants in that city, and

WHEREAS, the A. W. W. A. by meeting in Chicago in 1927 is offered the opportunity of being of very great service to the profession and the city officials by giving stimulus in focusing public attention to the water purification projects which have been proposed, and

WHEREAS, the City of Chicago has not entertained the A. W. W. A. since 1902, and is now desirous of doing so, and

WHEREAS, the hotel and convention facilities of Chicago are unequaled, and Chicago's train schedules place it easy of access from all sections of the country.

Now Therefore Be it Resolved by the Illinois Section of the A. W. W. A. that the Convention Committee of the A. W. W. A. and the district representative on the Executive Board be respectfully advised that it is the desire of the Illinois Section that the 1927 convention be held in Chicago.

The following officers were elected for the coming year: Chairman W. R. Gelston; Vice Chairman, G. C. Habermeyer; Treasurer, H. E. Keeler; Trustee, L. R. Howson.

The program follows:

WEDNESDAY, MARCH 24, 1926

9:30 a.m.

Report of Secretary. G. C. Habermeyer.
Report of Treasurer. H. E. Keeler.
Promotion of Municipal Bond Issues. W. R. Gelston.
Water Certificates to Finance Water Supply Plants in Illinois. Paul E. Green.
Operation of Electrically Driven Pumping Stations with Respect to Peak Loads of Power Company. J. A. Rue.
Semipublic Water Supplies and Approved Types of Wells in Illinois. Carl D. Gross and H. F. Ferguson.
Automatic Primers. F. H. Bradford.

1:30 p.m.

Rehabilitation Program for the Racine, Wis. Water Works. D. H. Maxwell.
The Quincy Reservoir. P. Hansen, R. S. Rankin, J. K. Giesey.
Small Town Water Works. Harold F. Hunter.
Tests of Strength Properties of Cast Iron Pipe. A. N. Talbot.
Experimental and Demonstration Apparatus at the University of Illinois
Friction in Water Pipe: Air Lift Pump: Discharge from Filter Manifolds. M. L. Enger.
Plumbing. H. E. Babbitt.
Trip through the laboratory and demonstration of apparatus.

6:30 p.m.

Annual Dinner, Urbana-Lincoln Hotel
Address of Welcome. M. S. Ketchum.
Response by Chairman. L. R. Howson.
Election of Officers.
Short talks by Beekman C. Little, Secretary of the American Water Works Association, and others.
The Water Works from the Architect's Viewpoint. V. A. Matteson.
A Trip Through Yellowstone (Courtesy of the Northern Pacific Railroad).

THURSDAY, MARCH 25, 1926

9:30 a.m.

Shallow Well Development. John Oliphant.
The Water Supply of the Chicago and Northwestern Railway. R. E. Coughlan.

The Water Supply of the Illinois Central Railroad. C. R. Knowles.
Duties of the Railway Water Service Inspector. J. P. Hanley.
Experiences in the Water Works Game. George W. Hanley.
Responsibility of Municipalities, Water Companies and Individuals for Water Borne Illness. Dr. I. D. Rawlings, and H. F. Ferguson.
Experiences with Cross Connections in Chicago. Arthur E. Gorman.

1:30 p.m.

The Quality of Lake Michigan Water and Water Supplies from Waukegan, Ill., to Gary, Ind. F. W. Mohlman.
Comparative Studies of Standard Methods and the Brilliant Green Bile Medium on Lake Michigan Water at Chicago. C. C. Ruchhoft.
Differential Tests for the Coli-Aerogenes Group of Bacteria. S. A. Koser.
Operation of the Hinsdale Water Softening Plant. Frank G. Danielson.
A Survey of Stream Pollution in Illinois. A. M. Buswell.
Stream Pollution and Sewage Purification. W. D. Hatfield.
Trips of plants of Champaign & Urbana Water Company and Urbana-Champaign Sanitary District.

ROCKY MOUNTAIN SECTION

Conference of Water Superintendents from Wyoming, Colorado and New Mexico

The Conference opened at 9:00 a.m. February 23, 1926, at Denver and proceeded according to the program.

During the second session, temporary officers were elected as follows: Chairman, P. E. Strouse, Water Supt., Rocky Ford, Colo., and Secretary, W. S. Rathbun, Engineer, Mt. States Inspection Bureau. These approinted a committee to investigate and report upon the formation of a permanent water works organization for this territory.

The report of the committee, presented at the morning session of the second day, recommended the formation of a Rocky Mountain Section of the American Water Works Association. This met with the unanimous approval of those in attendance. Permanent officers were then elected, and instructed to proceed with the formation of the Section, to include Wyoming, Colorado and New Mexico, and possibly later Idaho, Utah, Arizona and western Nebraska. The officers for the Section are: Chairman, P. E. Strouse, Water Supt., Rocky Ford, Colo.; Vice Chairman, A. W. Stedman, Water Supt., Canon City, Colo.; Secretary-Treasurer, D. E. Kepner, Sanitary Engineer, Colo. State Board of Health. The directors are: E. C. Gwillim, Water Supt., Sheridan, Wyo.; D. Z. Bell, Water Supt.,

U. P. R. R., Rock Springs, Wyo.; D. P. Porter, Water Supt., Pueblo, (North Side) Colo.; W. S. Rathbun, Engineer, Mt. States Inspection Bureau, Denver, Colo.; Paul S. Fox, Sanitary Engineer, New Mexico Bureau of Public Health, Santa Fe, N. Mex.; and Cicero Oggle, Water Supt., East Las Vegas, N. Mex.

The dinner at the evening session of the first day, held at the Albany Hotel, was given through the courtesy of six water works supply houses, including:

Colorado Fuel & Iron Company
Crane-O'Fallon Company
Hendrie & Bolthoff Mfg. & Supply Company
Neptune Meter Company
National Tube Company
Wallace & Tiernan Co., Inc.

Transportation to the new Marston Lake Filter Plant of Denver was provided by the Board of Water Commissioners, and the party was escorted by Mayor Stapleton, and R. S. Sumner, Burton Lowther and O. J. Ripple, General Manager, Chief Engineer and Filter Superintendent respectively, of the water works. This was an exceedingly interesting trip, as the new plant is modern and somewhat unique, employing anthracite coal as a filtering medium and being equipped for "air wash."

A total of 100 men, water superintendents, local health officers and water works engineers from the three states, registered for the Conference. They were very generous in their praise of the meetings, and, to all appearances, the Conference was a success.

The program follows:

TUESDAY, FEBRUARY 23

Morning Session, 9:00 a.m.

Address of Welcome. Dr. S. R. McKelvey, Secy., Colo. State Board of Health.

Early Examination of Water Supply in Colorado. Dr. Wm. C. Mitchell, Bacteriologist, Colorado State Board of Health.

A Bacteriological Study of the Las Animas River. Paul S. Fox, Sanitary Engineer, New Mexico Bureau of Public Health.

Microscopic Organisms Causing Tastes and Odors in Water. George Turre, Chemist, Denver Municipal Water Company.

Chlorination of Water. J. A. Strang, Wallace & Tiernan Co., Newark, N. J.

Afternoon Session, 2:00 p.m.

Watershed Sanitation. Dr. Sherman Williams, Member Colo. State Bd. of Health.

Financing Water Works Projects. C. N. Phillips, Jas. H. Causey Co., Investment Bankers, Denver.

Fire Protection. W. S. Rathbun, Engineer, Mt. States Inspection Bureau.

Description of Rocky Ford Filtration Plant. P. E. Strouse, Water Supt., Rocky Ford, Colorado.

Design and Maintenance of Distribution Systems. D. D. Gross, Office Engineer, Denver Municipal Water Company.

Dinner Session, 6:30 p.m.

State Health Department Service on Water Supplies:
Wyoming. Dr. G. M. Anderson, Wyoming State Health Officer.
New Mexico. Paul S. Fox, New Mexico State Sanitary Engineer.
Colorado. Dana E. Kepner, Colorado State Sanitary Engineer.

Motion Pictures. The Manufacture of Pipe. Courtesy National Tube Co.

Iodin and Goitre. Dr. Omer R. Gillett, Health Officer, Colo. Springs.

U. S. Public Health Service and Municipal Water Supplies. I. W. Mendelsohn, Associate Sanitary Engineer, U. S. P. H. S.

WEDNESDAY, FEBRUARY 24

Morning Session, 9:00 a.m.

Discussion of Bookkeeping Systems for Municipal Water Companies. Led by P. E. Strouse, Water Supt., Rocky Ford, Colo.

Discussion of Formation of a Section of the American Water Works Association. Led by W. S. Rathbun, Engineer, Mt. States Inspection Bureau.

Round Table Discussions, Miscellaneous.

Afternoon Session, 1:30 p.m.

Trip to New Marston Lake Filter Plant. (Courtesy of Denver Municipal Water Company).

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12:** 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

An Aspect of the Hydraulic Jump Problem. A. P. FLOCKART. Eng. News-Rec., **95:** 728, October 29, 1925. Brief illustrated discussion.—*R. E. Thompson.*

Pipe Pusher Eliminates Necessity of Digging Shallow Trenches. Eng. News Rec., **95:** 735, October 29, 1925. One-man pipe pushing machine manufactured by Grant Mfg. Co., Council Bluffs, Ia., described and illustrated. Claimed that all possibility of bending is eliminated. Speed capacity is approximately 3 lengths of pipe per hour.—*R. E. Thompson.*

Grouting Reinforces Rock at Oak Grove Surge Chamber. Eng. News-Rec., **95:** 746–9, November 5, 1925. When water was admitted to surge tank of Oak Grove hydro-electric plant of Portland Electric Power Co., on Clackamas River, Ore., concrete lining cracked, resulting in considerable leakage. Grouting was selected in preference to steel lining as method of repair and after two successive grout treatments, which are described in some detail, leakage was reduced from 2–3 to 0.42 second feet.—*R. E. Thompson.*

A Manual for Building and Operating Sliding Forms. R. F. EGELHOFF. Eng. News-Rec., **95:** 786–92, November 12, 1925. Detailed illustrated discussion of employment of sliding forms in concrete construction.—*R. E. Thompson.*

Convenient Scheme for Ordering Pipes and Fittings. Eng. News-Rec., **95:** 809, November 12, 1925. Scheme described for laying out and listing pipe details in water circulating systems, etc., developed by Southern Pacific R.R. —*R. E. Thompson.*

Equipment Measures Concrete Aggregates by Weight. Eng. News-Rec., **95:** 819, November 12, 1925. Brief illustrated description of equipment manufactured by Blaw-Knox Co., Pittsburgh.—*R. E. Thompson.*

Cement Lining in Wrought Iron and Steel Pipe. Eng. News-Rec., **95:** 653, October 15, 1925. Cement-lined pipe, $\frac{3}{4}$ to 4 inches in diameter, manufactured by Cement Lined Pipe Co., Lynn, Mass., described briefly, and standard lead-

lined fitting, by means of which protective lining is made continuous at joints, illustrated. Both lead and cement linings are guaranteed against injury during shipping and handling.—*R. E. Thompson.*

Why Water Mains Burst. H. F. DUNHAM. Eng. News-Rec., **95**: 646, October 15, 1925. Dunham claims existence of errors in factors of safety adopted by American Water Works Association for cast iron pipe.—*R. E. Thompson.*

Small Vacuum Pump for Priming Centrifugal Pumps. Eng. News-Rec., **95**: 652, October 15, 1925. Brief illustrated description of dry-type vacuum pump manufactured by Barrett, Haentjens & Co., Hazleton, Pa., for priming centrifugal pumps.—*R. E. Thompson.*

Steel Multiple Stops Swirling in Surge Chamber. Eng. News-Rec., **95**: 709, October 29, 1925. When additional unit was recently added to three already in service at White River plant of Puget Sound Light & Power Co., Seattle, Wash., it was found that new combination of hydraulic conditions, not contemplated in original design, caused violent swirling in surge chamber. Steel manifold in bottom of surge chamber which effectively eliminated difficulty without interfering with service demands, described briefly and illustrated.—*R. E. Thompson.*

Large Multiple-Arch Dam Being Built in Italy. J. B. LIPPINCOTT. Eng. News-Rec., **95**: 710–1, October 29, 1925. Illustrated description of unusual multiple-arch dam with maximum height of 170.6 feet and length of 722 feet, known as Tidone Barrage, now under construction on Tidone River in northern Italy. Cement plant with vertical kilns was constructed especially for the work.—*R. E. Thompson.*

Imperial Valley Drainage Problems—Progress in Solution. D. W. MURPHY. Eng. News-Rec., **95**: 804–7, November 12, 1925. Illustrated description of works for control of ground water in Imperial Valley (California and Mexico). —*R. E. Thompson.*

Electric Pumping at Water Stations. Eng. News-Rec., **95**: 807–8, November 12, 1925. Brief data given on use of electric power for pumping in railroad water stations. Under favorable conditions electrically operated stations are cheaper to install and maintain than steam plants. Although fuel-oil engines are considered cheapest source of power, this is sometimes offset by decreased cost of attendance for electrical stations. Motor drive is employed with every type of pump, but it is particularly adapted to direct-connected centrifugal pumping units.—*R. E. Thompson.*

Medium Pressure Valves Have New Features. Eng. News-Rec., **95**: 819, November 12, 1925. Brief illustrated description of new medium pressure bronze valves with removable disks manufactured by Jenkins Bros., N. Y.— *R. E. Thompson.*

Water Power Investigations by the Geological Survey. B. E. JONES. Eng. News-Rec., 95: 830–1, November 19, 1925. Outline of activities of United States Geological Survey in collecting data on river flow, geological conditions, etc. To date 16,000 miles of river courses have been surveyed. Gaging stations now being maintained number 1,673.—*R. E. Thompson.*

Pompeiians Laid Water Mains on Both Sides of Street. M. M. O'SHAUGHNESSY. Eng. News-Rec., 95: 850, November 19, 1925. Attention drawn to fact that in Pompeii, 2000 years ago, 2 to 3-inch lead water mains were laid in the narrow sidewalks.—*R. E. Thompson.*

New Work on Specifications for Materials. Eng. News-Rec., 95: 869, November 26, 1925. Brief data on work carried out or in progress with regard to specifications of American Society for Testing Materials given. Experiments on corrosion of copper-bearing and non-copper-bearing steels indicate that resistance to corrosion is decidedly greater when copper is present.—*R. E. Thompson.*

Leakage Tests of Cast Iron Force Main at Columbus, Ohio. JOHN C. PRIOR. Eng. News-Rec., 95: 870–2, November 26, 1925. Data given on leakage test of new 36- and 42-inch cast iron main. Maximum leakage allowed by contract was 528 gallons per 24 hours per inch-mile of pipe, and average leakage (corrected to standard pressure of 110 pounds) during 6-day test was only 87.3 gallons. Concluded that one-half maximum allowable leakage could be obtained with little difficulty and that leakage as low as 100 gallons per inch-mile per 24 hours could be obtained under conditions and pressures obtaining on this line. Total cost of 3 miles of new main was just under $500,000. Pipe and fittings were purchased and delivered along pipeline for approximately $270,000.—*R. E. Thompson.*

Fabricating Strength of High-Strength Steel. Eng. News-Rec., 95: 878, November 26, 1925. Brief data given derived from studies carried out in connection with extending use of high-strength structural steel in Germany. General conclusion drawn is that as compared with ordinary soft structural steel (54,000 to 64,000 pounds ultimate) extra shop cost of high-strength (68,000 to 82,500 ultimate) is 15 to 20 per cent.—*R. E. Thompson.*

Welded Headers Too Rigid for Meter Banks. Eng. News-Rec., 95: 881, November 26, 1925. Brief illustrated description of connection developed by Spring Valley Water Co., San Francisco, for banks of 2-inch meters, which are employed in preference to single meters of large size.—*R. E. Thompson.*

Arch Dam Repaired by Fills Above and Below Structure. JOHN E. FIELD. Eng. News-Rec., 95: 953–4, December 10, 1925. In investigation of concrete arch dam 50 feet in height and 300 feet in span for city of Manitou, Colo., two outstanding faults in construction were obvious—use of disintegrated granite as sand, and poor workmanship in mixing and placing. Considerable disintegration had taken place as result of seepage and by freezing of saturated

concrete, and there was a heavy deposit—½ inch in thickness in places—of calcareous material on lower face of dam. Repairs carried out consisted of partial earth fill on upper side and backing on lower side to full height of dam. Construction joints in concrete were also raked out and filled with 1:2 mixture of cement and clean sound quartz sand.—*R. E. Thompson.*

Water Meters Accurate After Long Service. Eng. News-Rec., 95: 881, November 26, 1925. During conversion of meters on residence services in San José, Calif., large number of meters which had been in use for periods ranging up to 15 to 20 years were tested. Of 955 meters tested in 1 month, average service of which was probably 7 to 8 years, only 3 were found to run fast.—*R. E. Thompson.*

Small Flexible Ditcher For Use in Public Service Field. Eng. News-Rec., 95: 895, November 26, 1925. Brief illustrated description of machine manufactured by Parsons Co., Newton, Ia., which digs 12 to 24 inches wide, changing width by inches, and to maximum depth of 7 feet.—*R. E. Thompson.*

Lining Procedure in Holland Vehicular Tunnel. Eng. News-Rec., 95: 902–7, December 3, 1925. Illustrated description of procedure employed in lining tunnel under Hudson River first with concrete and then with glazed tile.—*R. E. Thompson.*

Motor Unit Completely Closes Valve Before Motor Stops. Eng. News-Rec., 95: 931, December 3, 1925. Brief illustrated description of electrically driven valve operating mechanism, manufactured by Coffin Valve Co., Neponset, Mass., which completely closes valve before motor stops, thus eliminating making of final tightening by hand.—*R. E. Thompson.*

High Wastage of Water at Sacramento, Calif. Eng. News-Rec., 95: 957, December 10, 1925. Provision in city charter at Sacramento prohibits installation of meters on water services to residences, and as result, consumption and water waste are very high. System serves 85,000 water users, and minimum night flow is at rate of 12 m.g.d., and average night rate of flow is 15 m.g.d. During 1924 daily average consumption was 22 m.g.d. and per capita consumption, 270 gallons per day. For short periods consumption rate ranges up to 600 gallons per capita per day. In house-to-house inspection recently undertaken 98 per cent of premises visited had leaky fixtures. Inspection and corrective measures under way are expected to decrease waste 15 to 20 per cent. —*R. E. Thompson.*

Flood Protection Works Progress at Peru, Ind. Eng. News-Rec., 95: 962–3, December 10, 1925. Illustrated description of Peru flood protection works, undertaken as result of loss sustained in great Ohio Valley floods. City is situated mainly on low ground along both sides of Wabash River.—*R. E. Thompson.*

Belt Conveyor Handles Concrete to Slopes of Drainage Canal. Eng. News-Rec., **95**: 964–5, December 10, 1925. Brief illustrated description of concreting plant employed on River des Peres drainage works in St. Louis.—*R. E. Thompson.*

Large Channel-Dredging Project at Portland, Ore. Eng. News-Rec., **95**: 982–4, December 17, 1925. Illustrated description of channel improvement work on 12-mile stretch of Willamette River between Portland and Columbia River.—*R. E. Thompson.*

Large Pipe in Trench Moved Bodily by Motor Trucks. Eng. News-Rec., **95**: 966, December 10, 1925. Brief illustrated description of method employed in Sacramento in moving 720-foot length of 36-inch water pipe to parallel position some 9½ feet distant. Trench sufficiently wide to allow pipe to be rolled to new location was excavated and pipe was moved bodily by 5 motor trucks. When pipe was reconnected no leaks were found. Cost of work was $2.784 per foot.—*R. E. Thompson.*

Dam Built on Miter Lock Gate Principle. E. W. LANE. Eng. News-Rec., **95**: 967, December 10, 1925. Small mill dam near Ithaca, N. Y., 35 feet wide at top and sustaining head of about 12 feet, constructed of timber on miter lock gate principle, described and illustrated.—*R. E. Thompson.*

Does Silting Affect Cutting Power of Streams? Eng. News-Rec., **95**: 968–9, December 10, 1925. Discussion of article of L. M. LAWSON by HERMAN STABLER, and reply by author.—*R. E. Thompson.*

Colorado River Problems. Eng. News-Rec., **96**: 56–7, January 14, 1926. Conditions re river control and allotments of water for power, irrigation, etc., discussed.—*R. E. Thompson.*

Pueblo Flood Protection. Eng. News-Rec., **96**: 84, January 14, 1926. Work of Pueblo Conservancy District outlined.—*R. E. Thompson.*

Hetch Hetchy Project. Eng. News-Rec., **96**: 84, January 14, 1926. Status of project outlined. Expenditure to date, exclusive of interest, totals $44,000,000.—*R. E. Thompson.*

Building 29-Foot Concrete Arch Sewer at Richmond, Va. Eng. News-Rec., **95**: 996–7, December 17, 1925. Shockoe Creek sewer construction described and illustrated.—*R. E. Thompson.*

Baton Rouge, La. Eng. News-Rec., **95**: 998–9, December 17, 1925. Water derived from artesian wells 1300 to 2200 feet deep, is supplied by private company. Electrical pumping units have been recently installed to meet peak demand.—*R. E. Thompson.*

Countersunk Rivets as Strong as Buttonhead in Tests. Eng. News-Rec., **95**: 1023, December 24, 1925. Tests of 168 riveted joints reported by J. B. Kommers in Bull. of University of Wisconsin, Vol. 9, No. 5, indicate that countersunk rivets are as strong in shearing and bearing resistance as buttonhead rivets.—*R. E. Thompson.*

Silt and Channel Conditions in Colorado River Delta. S. L. ROTHERY. Eng. News-Rec., **95**: 1068–71, December 31, 1925. Data on conditions in Colorado River Delta.—*R. E. Thompson.*

Montgomery, Ala. Eng. News-Rec., **95**: 1075–6, December 31, 1925. Water supply system is in charge of a commission but city engineer has practical control of all properties. Heretofore extensions to system were financed by bond issues, etc., but recently practice has been adopted of not installing mains and hydrants until estimated expenditure has been collected from property owners.—*R. E. Thompson.*

Impulse Wheel Shows Efficiency of 93 Per Cent. Eng. News-Rec., **95**: 858, November 19, 1925. In recently conducted test on Pelton water wheels in Pit River No. 3 plant of Pacific Gas and Electric Co., in northern California, efficiency of 93 per cent was certified to by representatives of power company, manufacturers, and independent engineer. Unit has nominal rating of 29,000 h.p., and was under normal head of 280 feet during test.—*R. E. Thompson.*

Blowpipe Saves 12-Mile Water Supply Line for Road Contractor. Cont. Rec., **39**: 987, October 7, 1925. Repair by oxywelding of 12-mile 3-inch steel pipe which had been badly ruptured by freezing described briefly. Length of splits in pipe varied from 3 to 50 inches.—*R. E. Thompson.*

Construction Procedure and Methods on the Alouette-Stave Tunnel. Cont. Rec., **39**: 1054–7, November 4, 1925. Illustrated description of construction of water tunnel 3485 feet long and of arched section 178.5 square feet in area, to convey water to power house of Br. Columbia Electric Railway Co., located at Stave Lake.—*R. E. Thompson.*

Some Further Interesting Views of Stave Lake Power Plant. Cont. Rec., **39**: 1096–8, November 18, 1925. Description of further phase of Stave Falls power development, capacity of which is 87,500 h.p.—*R. E. Thompson.*

Alouette Dam Nearing Completion. Cont. Rec., **39**: 1112, November 18, 1925. Brief data on construction of concrete Alouette Dam, 1000 feet in length, which will raise water level of Alouette Lake 45 feet.—*R. E. Thompson.*

Norman Dam Power Development. S. T. MCCAVOUR. Cont. Rec., **39**: 1158–60, December 9, 1925. Description of dam and power development on western outlet of Lake of the Woods.—*R. E. Thompson.*

Failure of Dam in Wales Due to Washout Under Foundation. Eng. News-Rec., **96**: 12–3, January 7, 1926. Illustrated description of failure of old concrete dam on Lake Eigiau on November 2, 1925, as result of washout due to inadequate foundation footings and poor concrete. Water discharged caused complete failure of earth-fill dam with concrete core wall on Lake Coedty. First and second mentioned dams are 1200 and 900 feet respectively above town of Dolgarrog and rush of water down steep hillside resulted in 16 deaths and considerable property damage.—*R. E. Thompson.*

Efficiency Test on High-Head Reaction Turbine. Eng. News-Rec., **96**: 18–19, January 7, 1926. Tests recently made on Unit 1 of Oak Grove plant of Portland Electric Power Co. described and results tabulated and shown graphically. Turbine is vertical reaction wheel rated at 35,000 b.h.p., designed for effective head of 849 feet with prescribed generation speed of 514 r.p.m. Tests indicated efficiency of 90 per cent notwithstanding fact that effective head was 882 feet.—*R. E. Thompson.*

Water System for Humberstone, Ont. Cont. Rec., **39**: 1138–40, December 2, 1925. Recently completed water distribution system described and illustrated. Filtered and chlorinated Welland Canal water will be purchased from Port Colborne.—*R. E. Thompson.*

Practical Hints on Installation and Care of Valves. Eng. News-Rec., **95**: 1050, December 24, 1925. Practical suggestions re valves, derived from catalog of Kennedy Valve Mfg. Co., Elmira, N. Y., reproduced, included in which are following: (1) Avoid wrench strain. (2) Don't cut pipe threads too long. (3) Eliminate dirt. (4) Put pipe compound or cement on pipe thread—not on valve thread. (5) Keep valve tightly closed while connecting to pipe. (6) Blow out valve thoroughly before putting into service. (7) Provide ample support for maintaining alignment. (8) Don't apply wrench to hand wheel. (9) Open valve gradually. (10) Inspect regularly—operate between limits at least once per month. (11) Protect from frost.—*R. E. Thompson.*

Afforestation of Catchment Areas. J. R. Davidson. Water and Water Eng., **27**: 493–497, 1925. The forested watershed is at a distinct advantage over those freed from trees. Among the advantages are more regular yield, and less erosion. Although opinions on the matter differ, it seems that more water is yielded by forested area since loss due to transpiration is less than evaporation losses of the bare watershed. State aid in forestation is available to water authorities in Great Britain either as grants, as profit-sharing agreements with the state, or as direct lease by the state. Review is given of work accomplished by Birmingham, Glasgow, Liverpool, and Manchester.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

New Water Works Plant for the City of Tallin (Reval), Esthonia. Anon. Water and Water Eng., **27**: 437–8, 1925. A rapid sand filter installation of 5.5 million Imp. gallons capacity using air agitation of sand bed, and designed to operate at the rate of 1.5 gallons per square foot per minute. Guarantees are

very severe. When heated to 120°F., water shall have no taste of mud, earth, fishy material, nor of Cl. Organic matter of filtered water expressed as albuminoid NH_3 shall not exceed 0.5 p.p.m. Filtered water must be neutral to litmus at 175°F. and must not contain more than 20 bacteria per cubic centimeter when raw water contains 3000 per cubic centimeter. Bact. coli must be absent from 100 cc.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

The Iodoform Taste of Chlorinated Water. B. Adams. Medical Officer, Water and Water Eng., 27: 435–6, 1925. A decided taste which could not be distinguished from that of chlorophenols was given by 1 part per 1000 million of iodoform. Mere trace of alcohol or acetone with I in alkaline water will give iodoform reaction. By adding 0.2 p.p.m. I to water containing 1 p.p.m. alcohol or acetone vile tastes of iodoform were produced. Natural waters may have the necessary organic compounds set free from organic matter by bacterial action, and the I might be set free from its compounds by Cl. Chlorophenol tastes are developed instantly, but some time is necessary for the iodoform-like tastes to appear. Superchlorination and $KMnO_4$ will prevent iodoform tastes, but SO_2 does not remove them. Iodoform taste can be produced in water containing 0.005 p.p.m. I.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

Recent Studies on the Purification of Water and the Action of Various Waters on Lead and Copper Pipes. John C. Thresh and John F. Beale. Water and Water Eng., 27: 475–478, 1925. Experiments for Chelmsford Corporation at Langford with excess lime method of water purification have been successful and it is planned to erect full size plants. Water will be derived from two small streams, the Chelmer and Blackwater rivers, which are subject to great seasonal variation. Storage of several days supply will be provided to avoid using the water at unfavorable times. Treated water is to supplement existing well supply. Dosage used is 1 grain per gallon aluminum sulfate, followed by enough lime water to leave 10 p.p.m. excess CaO. Close regulation of dose is essential and special test using brilliant cresyl blue was devised for colorimetric control. Treated water is recarbonated to prevent development of precipitate and turbidity when mixed with well supply. Final treatment is rapid sand filtration. Excellent bacterial, organic-matter, and color removals are reported. Bacterial and algal after-growth did not occur. No odor was produced. The results of Adams (cf. preceding abstract) on phenol and iodoform tastes are discussed and avoidance of exposure of recently chlorinated water is advised as a means of avoiding tastes due to air-borne phenols from soot and the like. Difficulty with aftergrowths of Bact. coli and Bact. aërogenes in open reservoirs are at times too great to be due to contamination of water by fish, birds, etc. The presence of dead algae is shown to furnish food on which these bacteria thrive. The rôle of oxygen in plumbosolvency is important as the oxide of lead is soluble. The oxide of Cu is less soluble and hence O in water is less important with regard to Cu. Moreover Cu is less toxic than Pb and is not cumulative. Salinity of water modifies solvent action on Pb, but not on Cu. In case of both Pb and Cu any acidity is important, even that due to CO_2, since acids dissolve the oxides. Most im-

portant salts with regard to oxidation of Pb are carbonates and silicates. Carbonates do not prevent oxidation, but react with oxide forming insoluble oxycarbonate. Silicates prevent oxidation of Pb. Pipes of Cu may be used for all except acid waters. Acid waters should pass through Cu pipes only after lining with Sn. The Sn should not be alloyed with Pb as otherwise the Pb will be attacked.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

Determining Size of Chimneys. J. G. MINGLE. Power, **63**: 9, 332, March 2, 1926. Calculations of draft requirement and method of determining required height and diameter of chimney of minimum cost are shown.—*Aug. G. Nolte.*

Oil as a Boiler Fuel. A. F. BREWER. Power, **63**: 9, 349, March 2, 1926. Abstract of paper presented at Midwest Power Conference. To obtain maximum economy from fuel oil used as stationary boiler fuel certain specific facts must be observed. Oil must be properly preheated before firing. Atomization and the ease of pumping are general indications of proper preheating. To insure maximum of heat transfer, furnace and boiler heating surfaces must be clean. Too much excess air, whether intentionally or through leakage in boiler setting, must be avoided. Air required for combustion must be properly controlled. All oil leaks should be stopped, not only to prevent direct waste of oil, but also to eliminate fire hazard. Unwarranted fuel oil specifications should be avoided.—*Aug. G. Nolte.*

Sidelights on Scale and Corrosion. Power, **63**: 10, 362, March 9, 1926. Comments on Dr. R. E. HALL'S article "Boiler Water Conditioning With Special Reference to High Operating Pressure and Corrosion" delivered before recent Midwest Power Conference in Chicago. Adherent scales that grow in thickness are formed by deposition from the boiler water directly upon the surfaces where they are found. Each layer consists of many crystals the principal axes of which are at right angles to layer. Three substances deposit from boiler water in this manner, namely, calcium sulphate, calcium silicate, and magnesium silicate. Calcium carbonate by itself will not form this kind of scale, but it can become part of scale when loose crystals of it become entangled in matrix of one or more of the three substances mentioned. It can be demonstrated that when two strips of boiler steel are immersed in water containing some electrolyte, such as sodium sulphate, and water touching one strip contains more dissolved oxygen than that touching the other, whole affair will act like a battery if the strips are joined by a copper wire. In this case strip at which oxygen concentration is smaller is the anode, that is, current flows through the solution from that strip to the other, and back through external conductor to first strip. The anode loses weight by corrosion in proportion to amount of current developed. This action has been demonstrated by treating strips of clean boiler steel with distilled water, water containing sodium sulphate only, water containing sodium chloride only, and water containing both sodium sulphate and sodium cloride. Strips treated with above solutions corroded. Addition of sodium hydroxide to the solutions prevented this corrosion. Illustrated.—*Aug. G. Nolte.*

Alternating-Current Motors, Fundamental Principles. B. A. Briggs. Power, **63**: 10, 365, March 9, 1926. Construction of direct current and that of alternating current machines are compared. Such features as slip, pull-out torque, and induction generator are explained.—*Aug. G. Nolte.*

Factors Governing the Purchase or Generation of Power. W. A. Shoudy. Power, **63**: 10, 385, March 9, 1926. Abstract from paper before Philadelphia Engineers' Club, February 16, 1926. When problem becomes one of comparing cost of private with purchased power, following items must be considered: (1) Use factor (and, at times, load factor); (2) Fixed charges, covering interest on investment, depreciation (including amortization, etc.), insurance, rental and taxes; (3) Operating costs, including fuel, repairs, labor and miscellaneous.—*Aug. G. Nolte.*

Stoker-Fired Boiler Unit Develops High Efficiency. Power, **63**: 11, 398, March 16, 1926. Latest boiler unit installed in power plant of Brown and Sharpe Manufacturing Company comprises two Union water-tube boilers each made up of 4-inch tubes 18 feet long, with 3060 square feet of heating surface, set 9 feet 6 inches high under front header. Cross-baffling carefully laid out to maintain approximately constant gas velocity in all three passes. There is no economizer. Boilers set two in battery with division wall between furnaces. Under each boiler is four-retort Riley superstoker equipped with side-wall tuyeres and bridge-wall tuyere plates. Each stoker has projected grate area of 72 square feet. Furnace draft and under-fire air pressure are under automatic control, and steam- and air-flow meters, with a CO_2 recorder, guide operator in adjustment of manual controls. Stoker driven by reciprocating engine; other auxiliaries by alternating-current motors. Tests conducted with great care indicated unusually good efficiency. Overall efficiency was 83 per cent with less than 10 per cent combustible in refuse and with low under-fire air pressure, resulting in power consumption for forced draft fan of less than 0.1 kw.-hr. per thousand pounds of steam generated.—*Aug. G. Nolte.*

Powdered Coal at Ashley Street Station. E. H. Tenney. Power, **63**: 11, 404, March 16, 1926. Furnace changes undertaken to increase boiler capacity and efficiency and eliminate smoke. Relates experiences with eight boilers equipped with unit pulverizers, water-cooled furnace walls, and radiant type superheaters.—*Aug. G. Nolte.*

Hints on the Practical Operation of Air Ejectors. C. E. Colborn. Power, **63**: 11, 410, March 16, 1926.

Estimating Fabricated Pipe Costs. I. A. Butcher. Power, **63**: 11, 414, March 16, 1926. Comparison of costs of gas welded pipe work with a fitting job. Specific examples are given and valuable information imparted to enable an engineer to estimate or check costs for most power plant piping.—*Aug. G. Nolte.*

Operation of Diesel Engines. R. HILDEBRAND. Power, **61**: 13, 490, March 31, 1925. Notes on engine frames and cylinder liners. Illustrated.—*Aug. G. Nolte.*

Boiler Firing With Natural Gas. R. TULLIS. Power, **61**: 13, 494, March 31, 1925. Attendant danger of explosion when lighting burner is pointed out; proper procedure is given.—*Aug. G. Nolte.*

Effects of Impurities in Storage-Battery Electrolyte. G. W. VINAL and G. N. SCHRAMM. Power, **61**: 13, 509, March 31, 1925. Abstract from paper, "Storage Battery Electrolytes," presented at Midwinter Convention of A. I. E. E., New York City, February 9 to 13, 1925. Satisfactory operation of storage battery depends largely upon physical and chemical properties of electrolyte. Experiments in progress at Bureau of Standards to determine quantitatively effect produced by various impurities on rate of sulphation of storage-battery plates. Method involves determination of weight of plates while suspended in solution. Various impurities were added to pure electrolyte, 1.250 specific gravity, and effects produced judged by change in weight of plates. Impurities that affect negative plate only, may be divided into two classes: (a) those deposited quickly in metallic state upon negative plate and producing appreciable gassing; these include platinum, copper and silver; (b) those chemical compounds that are reduced more slowly at the negative plate and result in little, if any, perceptible liberation of hydrogen; these include bismuth, antimony, arsenic and nitrates. Impurities affecting both positive and negative plates include iron, manganese, and chlorine. Impurities affecting positive plate only are organic compounds. Impurities producing little or no effect include sodium, calcium, magnesium, aluminum, zinc, cadmium, and mercury. Specifications for battery acid issued by many different agencies show wide divergence in permissible impurities. A table on the purity of sulphuric acid and solutions for battery use is included in this article.—*Aug. G. Nolte.*

Preventing Breakdowns of Electrical Equipment. C. R. CHACE. Power, **61**: 14, 529, April 7, 1925. Divides electrical apparatus failures into four classes and discusses, in considerable detail, proper inspection and maintenance methods.—*Aug. G. Nolte.*

An Obstructed Venturi Meter. R. W. ANGUS. Power, **61**: 14, 532, April 7, 1925. A 6 inch by 3 inch meter tube obstructed by large piece of wood. Large water bills started investigation. Meter was calibrated with wood in place and correction curve obtained, which enabled a very speedy and amicable adjustment of accounts.—*Aug. G. Nolte.*

Factors Bearing on the Design of Large Turbines. F. HODGKINSON. Power, **61**: 14, 550, April 7, 1925.—*Aug. G. Nolte.*

A New Base Exchanging Silicate for Water Softening. Power, **61**: 14, 551, April 7, 1925. Distinguished from other exchange silicates by its structure.

Called "Doucil." Is a fine cellular body having pores of submicroscopic dimensions. Prepared by complete gelation of a solution made from sodium silicate and sodium aluminate under such conditions of control that its properties are definite and reproducible. According to Mr. VAIL, vice-president of American Doucil Company, a cubic foot of the substance contains 25 pounds of anhydrous silicate capable under practical working conditions of absorbing 12,500 grains of calcium carbonate equivalent, i.e., a cubic foot of "Doucil" will soften 1250 gallons of 10-grain water in comparison with 270 gallons of the same water for a like volume of "greensand." Excessive amount of sodium chloride in water suppresses its action. Unsuited to treat waters high in hydrogen sulphide or water containing oil. Entire regenerating operation can be accomplished in 30 minutes.—*Aug. G. Nolte.*

Sea Water Corrosion of Condenser Tube Material. Power, **61**: 15, 567, April 14, 1925. Notes of laboratory tests on action of salt water on copper alloys are given. Many alloys successfully withstood a ten-year attack of sea water. As for copper-zinc alloys with 60 per cent copper and 40 per cent zinc, addition of small amount of tin increases life from two to more than ten years. Alloys unsuitable for condenser tubes are brasses containing more than 85 per cent or less than 70 per cent copper, as well as manganese bronze and aluminum bronzes.—*Aug. G. Nolte.*

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Operation of Diesel Engines. R. HILDEBRAND. Power, **61**: 13, 490, March 31, 1925. Notes on engine frames and cylinder liners. Illustrated.—*Aug. G. Nolte.*

Boiler Firing With Natural Gas. R. TULLIS. Power, **61**: 13, 494, March 31, 1925. Attendant danger of explosion when lighting burner is pointed out; proper procedure is given.—*Aug. G. Nolte.*

Effects of Impurities in Storage-Battery Electrolyte. G. W. VINAL and G. N. SCHRAMM. Power, **61**: 13, 509, March 31, 1925. Abstract from paper, "Storage Battery Electrolytes," presented at Midwinter Convention of A. I. E. E., New York City, February 9 to 13, 1925. Satisfactory operation of storage battery depends largely upon physical and chemical properties of electrolyte. Experiments in progress at Bureau of Standards to determine quantitatively effect produced by various impurities on rate of sulphation of storage-battery plates. Method involves determination of weight of plates while suspended in solution. Various impurities were added to pure electrolyte, 1.250 specific gravity, and effects produced judged by change in weight of plates. Impurities that affect negative plate only, may be divided into two classes: (a) those deposited quickly in metallic state upon negative plate and producing appreciable gassing; these include platinum, copper and silver; (b) those chemical compounds that are reduced more slowly at the negative plate and result in little, if any, perceptible liberation of hydrogen; these include bismuth, antimony, arsenic and nitrates. Impurities affecting both positive and negative plates include iron, manganese, and chlorine. Impurities affecting positive plate only are organic compounds. Impurities producing little or no effect include sodium, calcium, magnesium, aluminum, zinc, cadmium, and mercury. Specifications for battery acid issued by many different agencies show wide divergence in permissible impurities. A table on the purity of sulphuric acid and solutions for battery use is included in this article.—*Aug. G. Nolte.*

Preventing Breakdowns of Electrical Equipment. C. R. CHACE. Power, **61**: 14, 529, April 7, 1925. Divides electrical apparatus failures into four classes and discusses, in considerable detail, proper inspection and maintenance methods.—*Aug. G. Nolte.*

An Obstructed Venturi Meter. R. W. ANGUS. Power, **61**: 14, 532, April 7, 1925. A 6 inch by 3 inch meter tube obstructed by large piece of wood. Large water bills started investigation. Meter was calibrated with wood in place and correction curve obtained, which enabled a very speedy and amicable adjustment of accounts.—*Aug. G. Nolte.*

Factors Bearing on the Design of Large Turbines. F. HODGKINSON. Power, **61**: 14, 550, April 7, 1925.—*Aug. G. Nolte.*

A New Base Exchanging Silicate for Water Softening. Power, **61**: 14, 551, April 7, 1925. Distinguished from other exchange silicates by its structure.

Called "Doucil." Is a fine cellular body having pores of submicroscopic dimensions. Prepared by complete gelation of a solution made from sodium silicate and sodium aluminate under such conditions of control that its properties are definite and reproducible. According to Mr. VAIL, vice-president of American Doucil Company, a cubic foot of the substance contains 25 pounds of anhydrous silicate capable under practical working conditions of absorbing 12,500 grains of calcium carbonate equivalent, i.e., a cubic foot of "Doucil" will soften 1250 gallons of 10-grain water in comparison with 270 gallons of the same water for a like volume of "greensand." Excessive amount of sodium chloride in water suppresses its action. Unsuited to treat waters high in hydrogen sulphide or water containing oil. Entire regenerating operation can be accomplished in 30 minutes.—*Aug. G. Nolte.*

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pound Engine. **61**: 15, 586, April 14, 1925. Testing Tightness of Boiler Rivet; Six Tons per Twenty-four Hours Equivalent to One Gallon of Water per Minute; Charging Air Chamber When Suction Pressure is Above Pressure of Atmosphere; Setting Valve of Single Valve Engine; Cleaning Water Gauge Glass in Place; Rise of Boiler Pressure from Heat of Setting. **61**: 16, 625, April 21, 1925. Temporary Covering for Back Connection; Head Pressure Pumped Against; Why Pull of Potential Switch Coil is Weak; Importance of Oil Separator on Exhaust-Steam Heating Plant; Power Lost by Shafting Friction; Cutoff Inadmissable for Direct Steam Pump; Bridge Walls and Combustion Chambers for H. R. T. Boilers; Calibration of Pressure Shown by Indicator Diagram; Reading of Meter Dials; Leakage After Removal of Boiler Scale.—*Aug. G. Nolte.*

Iron Bacteria and Water-pipe Incrustation. DAVID ELLIS. Surveyor, No. 1757. September 18, 1925. Report upon investigation to ascertain relationship of iron bacteria and other organisms to iron incrustations inside water pipes. Exhaustive examination showed that nodular formation was not caused by presence of iron group, but by imperfect covering of pipes and that iron in nodules was definitely derived from pipes. Stated that while hard incrustations present a physical and chemical problem, and festoon, one that is purely biological, a peculiar ferruginous condition in drinking water is sometimes found, in which both biological and physical factors come into play. In this condition, discoloration has taken place, tint being the familiar yellow of newly formed ferric hydroxide. Iron is present in colloidal form due to exposure of iron to water owing to inadequate protection and presence simultaneously of larger numbers of bacteria than should be found in drinking water. Multiplication of bacteria brings about a change in constitution of water resulting in liberation of carbon dioxide.—*N. J. Howard.*

Report on the working of the King Institute for Preventive Medecine Guindy, Madras, India, 1923–24. J. CUNNINGHAM, Director. 1104 samples of water were examined during year, either chemically or bacteriologically. Synopses of reports on individual water supplies are given. Details of outbreak of gastro-enteritis showed epidemic to be caused by bacilli of dysentery group. Experimental filter plant at institute was utilized in testing effect of preliminary filming of slow sand filters with alum. Available results show method to be a promising one for certain types of water.—*N. J. Howard.*

Institution of Water Engineers 30th General Meeting, London, England. Surveyor, 1770, December 18, 1925. **Further Observations on the Biology of Jersey Waterworks.** W. RUSHTON and P. A. AUBIN. Remedial measures for dealing with algal growths should be taken before filtration stage. Little change takes place in water during winter months, active period being February to November. Two periods of excessive diatom growths and one of chlorophyceae occurred. Synedra present over 2000 per cubic centimeter in August. Asterionella present in October to extent of 31,184 per cubic centimeter without production of perceptible taste or odor. Absence of odor presumed to be due to high chlorides (75 p.p.m.). Temperature was not considered as determin-

ing factor for increase in diatoms. Copper sulfate was applied by means of fine spray up to 1 pound per million gallons. Great advantage claimed for spraying over methods commonly employed. When water contained daphnia in considerable quantities, trout fry attained lengths up to 9 inches, as against 4 inches when crustaceae were comparatively scarce. Periodicity of diatoms and chlorophyceae show that in these waters, they follow normal curves for increased numbers. When algae are destroyed, thereby starving the crustaceae, trout fry suffer accordingly. Presence of large numbers of asterionella without giving rise to taste and odor suggests that other factors may exist to cause taste and odor in other waters. Discussion of paper followed in which Sir A. C. HOUSTON, JOSEPH RACE, and Dr. RUSHTON took part. **An Analysis of Scottish Rainfall Records.** W. N. MCLEAN. Discussion by J. R. DAVIDSON, W. GLASSPOLE, D. HALTON, and THOMPSON. **Recent Studies in Water Purification and Action of Various Waters on Lead and Copper.** J. C. THRESH and J. F. BEALE. Details of Sir A. C. HOUSTON's method of excess lime are discussed in relation to certain supplies in England. Factors for purification by excess lime are time and amount of excess lime. In hard water treated, best results were obtained by using one part per 100,000 excess lime and allowing 24 hours for reaction. Total bacterial count was enormously reduced while B. coli was invariably absent in 100 cc. Organic matter was reduced by 50 per cent. Color was reduced to 10 p.p.m. Rapid precipitation and decolorization of water was brought about by using 1 grain per gallon alum applied before addition of lime. It was found to be more economical and efficient to add lime in form of lime water than as milk of lime. In regulating proportion of applied lime water to ensure correct excess of lime, brilliant cresyl blue was used as indicator. Water after treatment was recarbonated with carbonic acid. Quality of water and suitability for treatment were determined by color and turbidity tests. In dealing with chlorination of water, mention made of work of British chemist in showing relationship of atmospheric phenols to odors in treated waters. Rapid sand filtration alone is described as useless in removing B. coli from water; slow sand is vastly better, but not absolutely reliable. Excess lime and chlorine methods can alone be depended upon. Experiments showed that colon bacillus flourished on a weed designated as Enteromorpha intestinalis, which was found growing abundantly in a reservoir and filter beds and led to following conclusion being reached: "that B. coli can grow and multiply prodigiously on the surface of decaying growths, and this is a point of considerable practical importance, since it follows that B. coli found in water do not always indicate manurial pollution. Decaying weeds give rise also to an enormous multiplication of Bacillus aërogenes, a bacillus often confounded with B. coli." Zinc, iron, lead, and copper can slowly take up oxygen dissolved in water. Natural waters containing oxygen in solution slowly oxidize the metal and if oxide formed be soluble in water, it will enter into solution. There is no practical method of removing oxygen from solution in a water supply, but in the case of lead, by addition of silicate of soda effect of oxygen can be prevented, and addition of carbonate will convert any oxide formed into soluble oxy-carbonate which, coating the pipe, seems to prevent further action. In presence of excess of carbonic acid, or any other free acid, lead oxide or oxycarbonate is

dissolved. Copper pipe of a given length and strength is becoming cheaper than lead and is likely to come into general use. Authors think copper pipes of 99.7 per cent purity can be used for all ordinary waters, but if a water contains excess of carbonic acid, or traces of other acid, tinned copper pipe should be used, and the tinning should be guaranteed 99 per cent pure tin. It was found that on some pipe lined with a composition of 50 per cent tin and 50 per cent lead acid waters act nearly as vigorously as upon ordinary lead. Instructive discussion follows by A. E. CORNEWALL WALKER, Sir A. C. HOUSTON, JOS. RACE, C. H. ROBERTS, W. BURGESS, and W. PATTERSON.—*N. J. Howard.*

The Afforestation of Catchment Areas. J. R. DAVIDSON. Surveyor, 1771, December 25, 1925. Necessity is emphasized for reservation of home timber. Position of local authorities as regards afforestation and influence of forests upon climatic conditions and soil erosion are discussed. Failures in afforestation are said to have been caused by lack of skilled advice, organization, efficient labor, and supervision. Discussion of progress already achieved and of future development included.—*N. J. Howard.*

Chlorine in Sewage and Waste Disposal. J. C. BAKER. Can. Eng., **50:** 2, January, 1926. History and review showing development of chlorination in water and sewage treatment. Chlorine has been used in many forms; calcium hypochlorite, sodium hypochlorite, and gaseous, in aqueous solution, and experimentally as magnesium hypochlorite, as hypochlorous acid, and in combination with nitrogen as nitrogen trichloride and as chloramine. Sewage should not be allowed to become septic before treatment, as this increases amount of chlorine required. Domestic sewage requires between 3 and 20 parts per million; a dose of 5 to 10 parts will usually give a 95 to 99 per cent reduction in bacterial count. In tannery wastes high in organic matter 250 parts are required to kill the spore-bearing anthrax bacillus. Chlorine is being increasingly used for purifying bathing pools. Protection of oyster beds by means of chlorine is receiving increased attention. Theory of action of chlorine in sterilizing water and sewage is discussed. Evidence strongly in favor of view that sterilizing action of chlorine is not due to direct oxidation but to formation of some substance toxic to the organisms. Oxidizing power of chlorine itself can be considerably reduced by combination with ammonium to form either nitrogen trichloride or chloramine, without any loss in its sterilizing capacity and very little alteration of its sterilizing rate, though the compounds, particularly chloramine, have a relatively low oxidizing potential. Chlorine probably acts by attacking the lipoid protein surface of the cellular organisms and forming there some substance which interferes with further cell division, thereby stopping regeneration and resulting in the death of the organisms.—*N. J. Howard.*

Effluents from Ammonia Plants and Their Disposal. J. LEWIS BAILEY. Surveyor, **68:** 1749, July, 1925. Extract of paper read before Institution of British and American Societies of Chemical Engineers. As far back as 1911 Fowler found that phenol was more rapidly oxidized on a bacterial filter than

was thiocyanate. Soil bacteria are capable of decomposing phenol, ortho-, meta-, and para-cresol, and naphthalene. Spent gas liquor, diluted until oxygen consumed in 4 hours is 400 parts per 100,000, is amenable to biological treatment. Experiments were carried out at a gas works, with small bacterial filter, consisting of various sizes of screened clinker impregnated with cow dung and afterwards washed with water. Crude spent liquor containing 178 parts per 100,000 of phenol was passed through the filter and an average of 56 days operation showed phenol reduction of 94 per cent.—*N. J. Howard.*

Removing Dissolved Oxygen From Water. W. J. Risley, Jr. Chem. & Met. Eng., **33**: 3, 163, March, 1926. If last trace of oxygen is removed from water no corrosion will take place. Where boiler feed water is first pumped through an economizer, 0.2 cc. of oxygen per liter will cause pitting. Considering both temperature and oxygen content, maximum corrosion is probably at about 150° to 170°F. It is feasible to completely remove all oxygen at temperatures as low as 140°F. by boiling under vacuum. Oxygen may also be removed by passing the water through tank containing large amount of expanded iron.—*John R. Baylis.*

Progress Report of Special Committee on Standard Construction Contracts. Proc. Amer. Soc. Civ. Eng., **52**: 3, 225–41, March, 1926. Contains standard contract for engineering construction issued by Joint Conference on Standard Construction Contracts, February, 1925. Following are members of Joint Conference: Am. Association of State Highway Officials, Am. Engineering Council, Am. Institute of Architects, Am. Railway Engineering Association, Am. Society of Civil Engineers, Am. Water Works Association, Associated General Contractors of America, and Western Society of Engineers.—*John R. Baylis.*

Progress Report of the Special Committee on Steel Column Research. Proc. Amer. Soc. Civ. Eng., **52**: 3, 146–209, March, 1926. Committee has examined over 600 tests on steel columns. For axially loaded columns of slenderness ratio up to 50 or 60, effect of length is small, and strength of column, if properly designed, is primarily a function of elastic strength of metal. Any formula for calculating strength of columns should give values for short columns closely related to tensile yield point strength of the material, and for long columns, values approaching those given by Euler law. Report gives elaborate discussion of the various details of loading as affecting strength of columns. —*John R. Baylis.*

Progress Report of the Special Committee on Cement. Proc. Amer. Soc. Civ. Eng., **52**: 3, 210–22, March, 1926. Committee is studying chemistry of the setting of cement, conditions necessary to bring set about, type and form of compounds in cement which will produce best quality of material after set, effect on resulting set of aggregate and of foreign substances introduced into aggregate, and solubility of cement products.—*John R. Baylis.*

E.N.R. Annual Statistics of Cost and Volume. Eng. News-Rec., **96**: 86–7, January 14, 1926. In tabulation of construction contracts—E.N.R. statistics —those for water works during 1925 are shown to number 564, total value

being $69,368,000, compared with 582 in 1924 with total value of $61,445,000. E.N.R. cost volume index numbers are shown graphically for 1924 and 1925, and monthly tabulations are given for period 1914–1915 inclusive.—*R. E. Thompson.*

Concrete Pump Pit Sunk as an Open Caisson. B. STANLEY NELSON. Eng. News-Rec., **95**: 1078–9, December 31, 1925. Water works system of Vicksburg, Miss., comprises low lift pumps which elevate Mississippi River water into filter basin where it is clarified, and high lift pumps which deliver filtered water from storage into city mains and standpipe. At Vicksburg, Mississippi River has maximum recorded range of elevation from −6.5 to 55, and to enable pumping of raw water at extreme low river stage, pumps must be located in deep pit. Construction of pump pit, which was sunk as open caisson, described and illustrated.—*R. E. Thompson.*

Weight of Stoney Sluice Gates. E. W. LANE. Eng. News-Rec., **95**: 1082, December 31, 1925. Diagram given for estimating Stoney gates, based on data reported in literature.—*R. E. Thompson.*

Freezing in Wood-Stave Pipe at Everett, Wash. Eng. News-Rec., **95**: 1077, December 31, 1925. About 8 miles of 26½-mile continuous wood-stave pipeline which carries water supply from Sultan River is exposed and each winter some ice collects in exposed portion. Last winter unusually hard frost reduced diameter of line to 8 inches and for few days caused water shortage and resulted in considerable damage to pipe due to breaking off of upper half of stave at ends by expansion of saturated wood on freezing. This damage occurs to lesser extent every winter, even when ice is not formed. Measures employed in overcoming difficulty and in repairing pipe are outlined.—*R. E. Thompson.*

NEW BOOK

Industrial Water Supplies of Ohio. C. W. FOULK. Fourth Series, Bulletin **29,** Geological Survey of Ohio, published by The Geological Survey of Ohio, University Grounds, Columbus, Ohio. Price $1.00. The bulletin is divided into three parts: Part I presents general information about water and its behavior in use; Part II presents by chemical analyses the nature of the surface waters of the state; and Part III, the nature of the ground waters of the state. Part I covering 159 pages is presented under 11 main chapter headings as follows: (1) *Origin of the Impurities in Water.* The substances found in water are enumerated, their origin given, and the natural changes taking place are listed. (2) *Meaning of Water Analysis.* It is pointed out that the purpose of almost all water analysis is to answer one of the following questions: (a) Is the water safe to drink? (b) Is it suitable for industrial use? (c) Does it contain substances of medicinal value? The meaning of the results of sanitary and mineral analysis is explained in such a way as to permit the reader to answer these questions readily. (3) *Ways of Stating the Results of a Water Analysis.* Objections to hypothetical combinations are: (a) It is impossible to determine in a solution just how the bases and acids are combined; and (b) There is no

uniformity among chemists as to the methods followed in attempting to combine the bases and acids; all of which results in confusion. The ionic form of statement of analysis is explained together with graphical methods of representing the results. (4) *Calculating Hypothetical Combinations.* The general principles of calculating hypothetical combinations is explained and the methods of the Illinois Water Survey, Bureau of Chemistry, Hale & French are given. Factors are also given by the use of which hypothetical combinations can be computed very rapidly. (5) *Methods of Chemical Analysis.* Methods of analysis given follow closely those outlined in "Standard Methods of Water Analysis, published by the American Public Health Association. The behavior of water is discussed under several headings as follows: in the household; scale formation; corrosion; and foaming. (6) *Interpretation of Industrial Water Analysis.* Stabler's equations for determining in a mathematical form the coefficients of foaming, corrosion and scale formation are given and are much more useable for the water works chemists than as published by Stabler, because an explanation of the philosophy of the plan is given and the meanings of the terms in the equations are explained. (7) *Hardness and Water in the Household.* The behavior of water in the household is discussed principally from the standpoint of hardness and its bad effects. It is estimated that the money saving to each householder due to soft water in Columbus, Ohio, amounts to $23.00 per year. (8) *Scale, Boiler Compounds and Internal Treatment.* Scale, boiler compounds and internal treatment are treated under one chapter; cause of deposition and character of scale are given. The possible good and bad effects obtainable with boiler compounds are listed, and Hall's theory of formation of adherent scale and method of conditioning boiler water are given. (9) *Corrosion.* Nineteen pages are devoted to the subject of sub-aqueous corrosion. The electrolytic and other theories are explained in language that one without chemical training should have no trouble in understanding. (10) *Foaming and Priming.* Professor Foulk points out that contrary to the usual belief, foaming is not caused directly by concentration of sodium salts in the boiler because it has been demonstrated that clean, clear water containing higher concentrations of sodium salts does not foam. He advances a theory according to which soluble salts in the water, by creating a difference in concentration between the surface and the mass of the liquid, make possible the formation of films, which, if caused by the usual inorganic salts, sodium salts, for example, in a boiler water, are not of themselves viscous enough to have a more than momentary existence and therefore never cause serious trouble. But if at the same time finely divided solid matter is present, such as loose scale and sludge, the films will be stabilized and a persistant foam will result. (11) *Purification of Water for Industrial Use.* Under the caption "Purification of Water for Industrial Use," the following methods of purification are described: (a) Lime Soda-ash Method of Softening, Intermittent and Continuous; (b) Miscellaneous Reagents for Softening; (c) Softening by Heating; (d) Zeolites; and (e) Coagulation for Clarification and Decolorization. It is difficult to do this bulletin justice in an abstract because it contains so much valuable information that cannot all be enumerated. Personally, I regard it as the best written and most valuable contribution on industrial water supplies that has yet been published.—*Charles P. Hoover.*

INDEXES, VOLUME TITLE AND CONTENTS FOR VOLUME 15

Supplement to
Journal of the American
Water Works Association
December, 1926, Vol. 16, No. 6

SUBJECT INDEX

Acidity; corn canning and dairy wastes and, 527 seq.
see Hydrogen-ion concentration
Adel; water supply; cost, 551
Aden; water supply, 541
Aeration; corrosiveness and, 274
Akron, O.; coagulation, lime and, 276
goiter; iodine and, 222
sodium iodide treatment and, 411
typhoid, cross-connections and, 477
water works supervision, 140
Alabama State Dept. of Health; impounded waters, regulations, 37
Alameda, Cal.; cross-connections, experience with, 478
see East Bay Water Co.
Algae; characteristics, 496 seq.
copper sulfate treatment and, 499 seq.
health and, 496
softening, lime and iron sulfate, and, 156
troubles, 418
see Copper sulfate treatment; Microscopic organisms
Alkali treatment; relative costs of, 274
see Lime treatment; Soda ash treatment; Sodium hydroxide treatment
Alkalinity; alum equivalent, 278
see Calcium carbonate; Hydrogen-ion concentration
Alliance, O.; plant control, 140
Allis-Chalmers Machinery Co.; pump installation, 364
Alpine Canyon, Utah; goiter, iodine and, 223
Aluminum; corrosion of, 603
Aluminum sulfate; alkalinity equivalent, 278
cost, 155
see Chemical feed; Coagulation
American Engineering Council; water resources and, 41, 403
American Gas Association; cast-iron pipe standardization and, 412 seq.
American Public Health Association; Sedgwick Memorial and, 415
American Railway Engineering Association; railroad supplies, treatment, economy of, 635 seq.
American Society of Civil Engineers; thread specifications, 557
American Society of Mechanical Engineers; thread specifications, 557
American Society for Testing Materials; cast-iron pipe standardization, 412 seq.
American Telephone and Telegraph Co.; population, future, estimation and, 2
American Water Works Association; cast-iron pipe standardization, 412 seq.
Hill Cup award, 104
manual, resolution re, 421
meter specifications, 556 seq.
see California Section; Central States Section; Four-States Section; Illinois Section; Indiana Section; Iowa Section; North Carolina Section; Rocky Mountain Section
Ammonia; *see* Nitrogen as ammonia
Anabaena; characteristics; copper sulfate treatment, 503 seq.
Anopheles; storage reservoirs and, 35 seq.
see Mosquito
Aphanizomenon; characteristics, 503
Arizona; highway supplies, 367
Arlington, Mass.; consumption; metering; rates, 14 seq.
Asheville N. C.; sterilization of mains and filters, 56 seq.
Ashland (Wis.) Water Co.; water quality, law suit re, 83
Ashtabula, O.; plant control, 140
Asphaltic compositions; centrifugal application to pipe, 689
Assessment; main extensions and, 258 seq.
Associated Factory Mutual Fire Insurance Companies; check valve, reliability, 416, 479
Attica, O.; plant control, 140
Austria; goiter, iodized salt and, 411
Automatic Primer Co.; Apco primer, 647 seq.

Bacillus aerogenes; characteristics, 164
differentiation from B. coli, 163 seq., 171 seq.
longevity in water, 166
in soil, 641 seq.
in water, concentration, pollution and, 165
see Bacteria, colon group
Bacillus, cloacae; characteristics, 173
Bacteria, ammonifiers; estimation of, 376
Bacteria, colon group; differentiation, 163 seq., 171 seq., 717
in fissure springs, 158 seq.
in soil, 641 seq.
types, incidence, interpretation, 167
see Bacillus aerogenes; Bacterium coli; etc
Bacteria, denitrifying; isolation, 383
in lake water, 371 seq.
in sea water, 369
Bacteria, nitrifying; in lake waters, 371 seq.
in soil and sea water, 369
Bacteria, slime-producing; growths, Baltimore, 31 seq.
Bacteriological examination; ammonifiers, estimating, 376
see Bacterium coli test
Bacterium coli; characteristics, 164, 173
differentiation from B. aerogenes, 163 seq., 171 seq.
intestine, relative proportion in, 641
longevity in water, 166
mains, new, and, 56 seq.
purification plant loading and, 281, 535
sodium thiosulfate and, 398
in soil, 641 seq.
see Bacteria, colon group
Bacterium coli test; brilliant green bile and, 717
Bacterium coscorba; characteristics, 173
Bacterium grunthali; characteristics, 173
Bacterium levans; characteristics, 173
Bacterium neopolitanum; characteristics, 173
Bacterium oxytocum; characteristics, 173
Bacterium pseudo coloides; characteristics, 173
Bacterium schafferi; characteristics, 173
Bacterium vesiculosium; characteristics, 173
Badin, N. C.; *see* Tallassee Power Co.
Baltimore, Md.; consumption, 213
corrosion, treatment and, 632 seq.
drought, experience, 213 seq.
filtration, 213, 675 seq.
H-ion concentration, determination, 26 seq.
lime treatment, pH control 32 seq., 274 seq.
metering, 218
Barnesville, O.; plant control, 140
Barton Springs; bacterial content, 162 seq.
flow, 160
Bass; Gambusia affinis and, 36
Bay City, Mich.; chlorination, taste and, 292 seq.
consumption, metering and, 348
Belmont, Mass.; metering; consumption; rates, 14 seq.
Beloit Water Company; private fire protection charge, law and, 704 seq.
Benzol; *see* Chlorobenzol
Berkeley, Cal.; *see* East Bay Water Co.
Bettendorf Water Company financing, 467
Billing; Detroit, Mich., and, 353
Black River Falls, Wis.; water supply, sub-surface dam and, 148 seq
Blaisdell sand washer; Montreal, Que., and, 666 seq.
Philadelphia, Pa., and, 673
water required, 671
Bloomington, Ill.; typhoid, cross-connections and, 477
Boiler; feed water, softening, economy of, 156, 227
oil burning, difficulties, 243 seq.
operation, 710 seq.
powdered coal and, drying, elimination, 456
see Railroad supplies
Booneville, Ind.; water supply, 709
Boston, Mass.; consumption; metering; rates, 4 seq.
Brass; *see* Pipe, brass
Brilliant green; *see* Bacterium coli test
Brockton, Mass.; metering; consumption; rates, 5 seq.
Brookfield, Ill.; financing, 659
Buckeye trenching machine; 507
Bucyrus, O.; plant control, 140
Buffalo, N. Y.; *see* Western New York Water Company

Builders Iron Foundry; rate controllers, 361

Cairo, Ill.; water supply, 236
Calcium carbonate; coatings; carbonation and, 628
coagulation, lime and iron sulfate, and, 628
corrosion and, 275, 623 seq.
formation, treatment for, 624 seq.
precipitation by bacteria, 369
solubility equilibrium, 623 seq.
see Hardness; Softening
Calcium hydroxide; saturated solution, pH of, 604
California; Railroad Commission; valuation and rate fixing and, 65 seq., 75
water works and, 64 seq.
Section; annual meeting, 103 seq.
membership; Hill Cup, 104
State Board of Health; cross-connections and, 473, 480
Cameron, Mo.; water supply, 281
Canning industry; *see* Corn canning
Canton, Mo.; filtration, 281
Carbon dioxide; coagulation and, 276 seq.
corrosiveness and, 273 seq., 618
determination, 277
lead corrosion and, 618
lime and soda treatment and, 274 seq.
see Carbonation
Carbonate; alkali, boiler foaming and, 634
see Calcium carbonate; Sodium carbonate
Carbonation; carbonate films and, corrosion and, 628
cost, Defiance, O., 154
Carbondale, Ill.; financing, 659
water supply, 235
Carterville, Ill.; financing, 659
Caruthersville, Mo.; iron removal, 282
Castor oil; anti-foaming compound, 659
Caustic soda; *see* Sodium hydroxide
Cedar Point, O.; plant control, 140
Central States Section; meeting, 712 seq.
Charlotte, N. C.; filters, air-binding, 47 seq.
Chattanooga, Tenn.; filtration, 299
Check valves; special F. M. type, 416, 479
unreliability of, 475 seq.
Chelsea, Mass.; consumption; metering; rates, 13, 15
Chemical feed; dry, 245, 714
Chemung River; tannery waste pollulution, 336 seq.
Chicago, Ill.; brilliant green bile study, 717
cross-connections, 587 seq.
metering, 345, 715
pumping station, 715
Chicago Board of Fire Underwriters; illegal cross-connections and, 590
Chicago and Northwestern Railroad; water supply, 634 seq.
Chillicothe, Mo.; water supply, 281
Chinic acid; colon group differentiation and, 171 seq.
Chlorides; pitting and, 607
Chlorination; 718
coagulation and, 467
control, residual chlorine and, 386 seq., 706
dosage, lime and iron sulfate and, 156
hypochlorite and, 60 seq.
mains, new, and, 52 seq.
Missouri and, 281
swimming pools and, 386 seq.
taste and odor; chlorobenzol plant waste and, 292 seq.
gas works; ammonia liquor and, 296
waste and, 295 seq.
main sterilization and, 59
phenol and, bacterial activity and, 297
seasonal occurrence, 297
sugar waste and, 293 seq.
wood distillation waste and, 295 seq.
see Prechlorination
Chlorine; determination, 389 seq., 391 seq., 706 seq.
Chlorobenzol plant waste; chlorination taste and, 292 seq.
Chlorophyceae; characteristics, 497 seq.
copper sulfate treatment and, 500 seq.
life of, 498
Cincinnati, O.; consumption; metering; rates, 4 seq.
Circleville, O.; typhoid, cross-connection and, 477
City manager system; 421
City Water Co.; private fire protection charge, law and, 704
Cladophora; characteristics; copper sulfate treatment, 501
Clathrocystis; characteristics, 502 seq.
copper sulfate treatment, 504

Cleveland, O.; consumption; metering; rates, 4 seq.
raw water quality, 489 seq.
swimming pool control, 386 seq.
Clinton, Mo.; water supply, 281
Clinton, Wis.; well, capacity, increasing, 150
Coagulation; acid with alum, 23, 276
carbon dioxide and, 276 seq.
chlorine and, 467
color removal, acid and, 276
corrosiveness and, 23, 276 seq.
dosage; color and turbidity and, 23
pH control, 32
H-ion concentration and, 22 seq., 63
lime and, 276
lime and iron sulfate; carbonate films, carbonation and, 628
corrosion and, 628
softening and, 154 seq.
temperature and, 337
see Aluminum sulfate; Chemical feed
Coagulation basin; cleaning, frequency, 418
foaming in, 42 seq.
Orlando, Fla., and, 245 seq.
Coal; powdered, drying, elimination, 456
Collecting gallery; Winner, S. D.; cost, 547 seq.
Color; foaming in coagulation basins and, 44 seq.
removal; alum; acid and, 276
dosage required, 23
reservoir, unstripped and, 63
tannery waste and, 336 seq.
Colorado; municipal water bonds and, 690 seq.
State Department of Health, water supplies and, 719
water supply examination, 718
Columbus, O.; consumption; metering; rates, 4 seq.
plant control, 140
Comal River; flow, 160
Concrete; deterioration, 620 seq.
Conneaut, O.; plant supervision, 140
Connecticut; highway supplies, 367
Connelsville, Pa.; water supply, 298
Consolidated Water Works Company; pipes, lining with cement, 685 seq.
water supply, 688 seq.
Consumers Power Company; water pollution, 295
Consumption;
Baltimore, Md., 213
Bay City, Mich., 348
cold weather and, 266 seq., 269
East Chicago, Ind., 265
East York, Ont., 520
Erie, Pa., 341, 345
Evanston, Ill., 358 seq.
future, estimating, 1 seq., 359 seq.
Gary, Ind., 266
Grand Rapids, Mich., 344 seq.
Greensboro, N. C., 62
industrial; 519 seq.
records, desirability, 2
Kitchener, Ont., 520
London, Ont., 509 seq., 523 seq.
metering and, 3 seq., 270, 344 seq., 509 seq., 523 seq.
Niagara Falls, N. Y., and, 347
night rates, 265 seq.
Ohio and, 345
Peabody, Mass., 219
population growth and, 1 seq.
pressure and, 518, 523
quantity classification, 6
rates and, 1 seq., 510 seq., 524
restriction, drought and, 218
sewer connections and, 518, 520
statistics, 4 seq., 12 seq.
tabulation, importance, 79
Wheeling, W. Va., 345
see Demand
Coolgardie, Australia; pipeline, corrosion, 544
Copper; determination, 652 seq.
price trends, 508
see Pipe, copper
Copper sulfate treatment; for algae, 499 seq.
residual copper, 650 seq.
Corn cannery waste; composition, 528 seq.
pollution and, 527 seq.
Corning, N. Y.; sewage disposal, 336
Corporation cock; practice, 507
Corrosion; *see* Brass; Concrete; Copper; Corrosiveness; Iron; Lead; Pipe, iron; Zinc
Corrosiveness; aeration and, 274
alkali treatment for, relative costs, 274
calcium carbonate films and; 623 seq.
treatment for producing, 624 seq.
carbon dioxide and, 273 seq.
carbonation and, 628
chlorides and, 607
coagulation and; 23, 276 seq.
lime and iron sulfate and, 628
corn canning and dairy wastes and, 527, 530
hardness and, 23
H-ion concentration and, 23, 272 seq., 599 seq.

lime treatment and, 274 seq., 624 seq.
negative ions and, 605 seq.
oxygen dissolved and, 272 seq. 544, 599 seq.
prevention; 271 seq., 623 seq.
economy of, 632
protective coatings, 275, 606, 613, 621 seq.
sodium carbonate and hydroxide treatment and, 274, 625 seq.
softening and, 157
sulfates and, 607
suspended matter and, 606
temperature and, 603, 630 seq.
Cowanesque River; tannery waste pollution, 338
Crenothrix; zeolite softening and, 232
Cross-connections; filters, private, and, 594 seq.
fire insurance rates and illegal, 590
fire protection systems and, 700 seq.
hot water installations and, 595 seq.
menace of, 472 seq., 587 seq.
regulations; California, 473
Chicago, Ill., 589 seq.
New York State, 415 seq.
swimming pools and, 594 seq.
typhoid and, 81, 477, 700
Curb cock; practice, 506 seq.
Cyanophyceae; characteristics, 498 seq.
copper sulfate treatment, 502 seq.
multiplication, rate, 499
odor and, 499
Cyclops; filter clogging and, 45

D. K. solution; available chlorine content, 55
main sterilization with, 55
Dairy; waste; composition, 530
pollution and, 527 seq.
Dam; failure, earthquake and, 407
sub-surface, 148 seq.
Dam springs; flow, 160
Davenport, Ia.; hydrant spacing, 225
main repair, 465
Davenport Water Co.; prechlorination, 253
settling basin improvement, 252 seq.
Dayton, O.; consumption; metering; rates, 13
Deerfield, Wis.; wells, 145
Defiance, O.; plant control, 140
recarbonation, cost, 154
Del Rio Ditch; flow, 160
Delavan, Wis.; well, 148
Delaware, O.; plant control, 140
Delaware, State of; highway supplies, 367
Demand; peak, storage and pump capacity and, 109 seq.
see Consumption
Denitrification; in lake waters, 371 seq.
rate, determination, 372
in sea water, 369 seq.
temperature and, 377
Denver, Colo.; filtration, 718
De Pere; well capacity, increasing, 144
Des Plaines, Ill.; water supply, 234 seq.
Desmids; characteristics; copper sulfate treatment, 500
Detroit, Mich.; consumption, 4 seq.
main extension, 353
meter reading, billing and collecting, 353
metering, 4 seq.
rates, 4 seq., 346, 353
services, 353 seq.
sewage disposal, 540
water supply, 540
Detroit River; pollution, 489, 540
Devils Lake; chemical and bacterial variations, 381 seq.
Diarrhea; cross-connection and, 477
epidemic, water-borne, 282, 477
Diatoms; characteristics, 498, 502
copper sulfate treatment, 502
odor and, 497
Disease; water-borne; liability for, 80 seq.
responsibility for, 717
see Diarrhea; Typhoid
Distribution system; design and maintenance, 719
future, provision for, 1
maps, importance, 78
see Main
Dow Chemical Company; water pollution and, 292 seq.
Drought; emergency measures; Baltimore, Md., 213 seq.
Peabody, Mass., 219 seq.
Du Pont de Nemours Co.; water pollution, 295 seq.
Dubuque, Ia.; water supply, 421
Duluth, Minn.; main extension financing, 260 seq.
metering, law and, 704
Durham, N. C.; filters, air-binding, 51
stream gaging, rainfall and evaporation study, 41

Earthquake; water supply system and, Santa Barbara, Cal., 404 seq.
East Bay Water Company; distributing reservoirs, 120
East Chicago, Ind.; consumption, 265, 270
metering, 265, 270
night flow, 265
East Liverpool, O.; plant control, 140
East St. Louis, Ill.; water supply, 298
East York Township, Ont.; consumption, 520
East Youngstown, O.; plant control, 140
Eastman Kodak Company; rapid fine sand filtration, 671
Edina, Mo.; water supply, 281
Electric motor; asynchronous-synchronous, 456
pump drive; motor capacity and, 454 seq.
overloading and, 454
power factor and, 455 seq.
Elgin, Ill.; typhoid, cross-connection and, 477, 700
Elkland Leather Company; waste, pollution and, 338 seq.
Elmira, N. Y.; tannery waste pollution and, 335 seq.
Endo medium; colon group differentiation and, 163
Engine, gasoline; noise elimination, 456
vs. oil, 454
see Engine, internal combustion
Engine, internal combustion; as standby; noise and, 454
Engine, oil; *vs.* gasoline, 454
see Engine, internal combustion
Erie, Pa.; consumption, 341, 345
financing, 346
metering, 341 seq.
rates, 341 seq.
waste restriction, 343 seq.
Erie Lake; water quality, 489 seq.
Essex Border Utilities Commission; water supply; sewage disposal, 540
Evanston, Ill.; consumption, 358 seq.
filter plant additions, 357 seq.
metering, 358
Evansville, Ind.; lime treatment, 276
Everett, Mass.; consumption; metering; rates, 13, 15
Everett, Wash.; typhoid; cross-connection and, 477
damage case, 80 seq.
Excelsior Springs, Mo.; iron removal, 282
Extension; frequency and, 1
law and, in California, 73 seq.
Extension financing; main; assessment for, 258 seq.
plants; municipal water bonds and, 690 seq.
water certificates and, 658 seq.

Fall River, Mass.; consumption; metering; rates, 5 seq.
Ferrous carbonate; solubility, pH and, 607
Ferrous sulfate; cost, 155
Festus, Mo.; water and sewage works, 285 seq.
Filter operators; experience required, 552
Filter sand; Goliad, 256
sampling of, 256 seq.
Filtration; B. coli and, 281
control, technical, 139
medium, anthracite coal, 718
Missouri and, 281
Ohio and, 139
theory of, 673 seq.
turbidity in effluent, automatic alarm and, 698
Filtration, double; Montreal and, 665
Filtration, rapid fine sand; *see* Filtration, slow sand
Filtration; rapid sand; air-binding, 42 seq.
alumina deposits, removal, 56
"cracking," 43, 47, 675 seq.
Evanston, Ill., and, 357 seq.
filter runs; softening and, 156
storage and, 63
manifold, discharge from, 716
microscopic organisms and, 45
Orlando, Fla., and, 244 seq.
sand, hydraulic grading of, 257
sterilization, 56 seq.
suspended matter, penetration of, 680 seq.
theory of, 679 seq.
Filtration, slow sand; air, removal of, 663, 671
Philadelphia, efficiency and sand data, 672
rapid fine sand; efficiency, 682 seq.
Montreal and, 663 seq.
reverse flow and, 663 seq.
suspended matter, character of, and, 676
washing, Blaisdell machine and, 666 seq., 673
Financing; Bettendorf Water Company, 467
bond issue, majority required, Missouri, 285
bonding limit, Missouri, 285

cost records and, 79
Erie, Pa., 346
fire protection revenue, inadequacy, 224
gratuitous water and, 70 seq., 259
investment; fire protection and, 70
return on, 69
invisible balance sheet, 481 seq.
loss, law and, 73
principles, 259 seq.
public relations and, 72 seq.
reports, principles, 469 seq.
see Extensions financing; Fire hydrants; Fire protection, private; Rates
Findlay, O.; plant control, 140
Fire hydrants; charge for, 522
spacing, 224 seq.
Fire insurance rates; illegal cross-connections and, 590
Fire protection; 719
ratings, Missouri, 284
revenue from, inadequacy, 224
water works investment and, 70
Fire protection, private; bleeding of system and, 700 seq.
charge for; 699 seq.
basis of, 703, 705
court decisions, 704 seq.
cross-connections and, 700 seq.
services; metering of; 702 seq.
court decisions, 703 seq.
size, restriction, 701 seq.
see Cross-connections
Fish; industrial wastes and, 292 seq.
Flat River, Mo.; filtration, 281
Florence, S. C.; main, new, clogging of, 53 seq.
Flow; in pipes; 654 seq.
velocity and friction, 655 seq.
Food; iodine content, 223
Fort Worth, Tex.; filter sand sampling, 256 seq.
Four-States Section; meeting, 417
Franklin, N. J.; typhoid, cross-connections and, 477

Galena, Ill.; water supply, 236
Galesburg, Ill.; water supply, 237
Gambusia affinis; mosquito larvae and; fish and, 36
Gary Heat, Light and Water Company; consumption, night rate, 266 seq.
metering, 266
waste detection, 267 seq.
water supply quality, 717
Gas works; ammonia liquor, phenol and, 296
General Electric Company; turbo-generator, 244
Glasgow, Mo.; filtration, 281
Glauconite; *see* Greensand
Glenview, Ill.; financing, 659
Goiter; hardness and, 410
iodine and, 222 seq., 409 seq., 719
see Sodium iodide treatment
Goshen, Utah; goiter, iodine and, 223
Grand Rapids, Mich.; consumption; metering, 4 seq., 344 seq.
rates, 4 seq.
Gray Bros.; Des Plaines, Ill., and, 234
Great Britain; riparian rights and, 534
Great Lakes; water quality, 489, 535
Great Lakes Region; water supply and sewage disposal, 489 seq.
Green Lake; chemical and bacterial variations, 381 seq.
Greensand; composition, 229
water softening with, 227 seq.
see Softening
Greensboro, N. C.; consumption, 62
impounding reservoir, effect of, 62 seq.
stream gaging, rainfall and evaporation study, 41
Ground water; collecting gallery and; cost, 547 seq.
sanitary hazards, 283 seq.
supplies; 536 seq.
vs. surface supplies, 537, 542 seq.
temperature, depth and, 160
see Water Supply; Well
Guadalupe River; flow, 160

Hamilton, Mo.; filtration, 281
Hannibal, Mo.; coagulation, chlorination and, 467
filtration, 281
lime treatment, 276
water supply, 280 seq.
Hardness; corrosiveness and, 23, 638
desirable amount, 534
goiter and, 410
health and, 152 seq.
meters and, 714
soap waste and, 155
taste and, 153 seq.
see Calcium carbonate; Softening
Hartford, Conn.; consumption; metering; rates, 4 seq.
Hayward, Cal.; *see* East Bay Water Company
Health; algae and, 496
sodium iodide treatment and, 409 seq.
softening and, 152 seq.
water and, 418
see Diarrhea; Disease, intestinal; Dysentery; Goiter; Typhoid

Henderson, N. C.; filters, air-binding, 46
Herkimer, N. Y.; typhoid, cross-connections and, 477
Herrin, Ill.; financing, 659
Higginsville, Mo.; water supply, 281
Highland Park, Mich.; water supply, 540
Highway supplies; placarding, 365 seq.
Hinsdale, Ill.; softening plant, 717
Holden, Mo.; water supply, 281
Hoosac Falls, Mass.; typhoid, cross-connections and, 477
Horsepen Creek; water quality, 62 seq.
Hot water installations; cross-connections and, 595 seq.
Huntington, N. Y.; sewage chlorination, 399
Huntington, W. Va.; water supply, 298
Huron, O.; plant control, 140
Hydrant; *see* Fire Hydrant
Hydrodictyon; characteristics; copper sulfate treatment, 500 seq.
Hydrogen-ion concentration; calcium carbonate solubility and, 624
coagulation and, 22 seq.
corn canning waste and, 527 seq.
corrosiveness and, 23, 272 seq., 599 seq.
dairy waste and, 527 seq.
galvanized iron and, 625
iron solubility and, 601 seq.
lead corrosion and, 618
lime treatment, automatic control and, 274 seq.
soda ash treatment, 625
storage and, 63
theory and, 272
treatment control and, 29
zinc solubility and, 615 seq.
Hypochlorite; preparation, apparatus for; cost, 60 seq.
sterilization with, 60 seq.

Illinois; ground water resources, 234 seq.
stream pollution, 717
water supplies; highway, 367
semi-public, 716
water works; bonding powers, 658
financing, 658 seq.
wells, approved, 716
Illinois Central Railroad; water supply, 717
Illinois Section; annual meeting, 714 seq.
India; Mota wells, 146
Indian Creek; mine waste pollution, 142 seq.
Indiana; fire prevention, 710
highway supplies, 367
Indiana Public Service Commission; private fire protection charge and, 703
Indiana Section; meeting, 709 seq.
Indiana State Board of Health; cross-connections and, 700
water pollution and, 712
Indianapolis, Ind.; consumption; metering; rates, 15
Industrial waste treatment; mine waste, 143
tannery waste, study, 338 seq.
Intake; blocking, sand and, 466
construction, Orlando, Fla., 245, 247, seq.
design, air and ice and, 536
filter air-binding and, 49 seq.
sites for, 536
International Filter Company; dry feed machines, 245
International Joint Commission on Pollution of Boundary Waters; purification plant loading, 535
Iodine; foods and, 223
goiter and, 222 seq., 719
in water; desirable amount, 223
pollution and, 223
see Sodium iodide treatment
Iodine treatment; sterilization and, 222
see Sodium iodide treatment
Iodized salt; goiter and, 222, 411
Iowa; water works in, 284
Iowa Section; annual meeting, 417 seq.
resolutions; manual, 421
stream pollution, 420 seq.
Iron; meter deposits and, 515
o-tolidin tests and, 706 seq.
solubility, pH and, 601 seq.
Iron bacteria; 606
Iron corrosion; cleaning and, 628 seq.
pitting and tuberculation; 606 seq.
protective coatings, 606, 613
sodium silicate treatment and, 630
theory of, 599 seq.
see Corrosiveness; Pipe, iron
Iron, removal; London, Ont., 515
Missouri and, 282
Iron sulfate; *see* Ferrous sulfate
Ithaca, N. Y.; typhoid, cross-connections and, 477
Ivanhoe Lake; water quality, 246 seq.

Jefferson City, Mo.; filtration, 281
operating costs, 346

Jeffersonville, Ind.; metering, 269
night flow, 268 seq.
Joplin, Mo.; filtration, 130
water supply, 280

Kansas; water works, 284
Kansas City Mo.; consumption; metering; rates, 4 seq.
filtration, 281
Kegonsa Lake; chemical and bacterial variations, 381, 383
Kelly Well Company; Winner, S. D., and, 546
Kentucky; highway supplies, 367
King City, Mo.; water supply, 281
Kirkville, Mo.; filtration, 281
Kirkwood, Mo.; iron removal, 282
Kitchener, Ont.; consumption; service charge, 520
Kokomo, Ind.; water supply, 298

Laboratory; chemical treatment control and, 419
field, motor truck and, 367
Lafayette, Ind.; water works electrification, 710
Lakeview, Utah; goiter, iodine and, 223
LaPlata, Mo.; filtration, 281
Las Animas River; bacteriological study, 718
Lawn sprinkler; underground, battery type, rates and, 77
Lawrence, Mass.; consumption; metering; rates, 5 seq.
Lawrence Experiment Station; filtration, 683 seq.
Lead; corrosion, 613, 618
price trends, 508
Leeds and Northrup potentiometer; 274 seq.
Lemont, Ill.; financing, 659
Lexington, Mass.; consumption; metering; rates, 14 seq.
Liberty, Mo.; iron removal, 282
Lima, O.; plant control, 140
Lime; cost, 155
Lime treatment; carbonate deposits and, 624 seq.
coagulation and, 276
control, pH and; 32 seq.
automatic, 274 seq.
corrosion and, 274 seq., 624 seq.
cost, 274
Little Rock, Ark.; filtration, 299
Lockport, Ill.; financing, 659
Logansport, Ind.; typhoid, cross-connections and, 700
London, Eng.; well supplies, 537
London, Ont.; consumption, metering and, 509 seq., 523 seq.
meters, practice, 512 seq.
rates, 510 seq., 523
services, practice, 505 seq.
water supply, 505 seq., 543 seq.
Lorain, O.; plant control, 140
Los Moras Spring; flow, 160
Louisiana, Mo.; diarrhea epidemic, 282
Lowell, Mass.; consumption, 5 seq.
cross-connections; regulations, 479
typhoid and, 477, 700
metering; 5 seq.
fire services and, court decision, 704
rates, 5 seq.
Lyngbya; characteristics; copper sulfate treatment, 502 seq.
Lynn, Mass.; Peabody emergency and, 219

Madison, Wis.; consumption; metering; rates, 5 seq.
Madison Water Company; water quality, law suit re, 83
Main; cleaning, results and cost, 249
earthquake and, 404 seq.
flushing of, 417
jointing, 105
laying, cast-iron, 129 seq.
moving of, 105
new, B. coli and, 56 seq.
relocation of, 288 seq.
sterilization; 52 seq., 711
taste and, 59
see Extensions financing; Pipe; Trench
Maine; highway supplies, 367
Malaria; storage lakes and, 35 seq.
Malden; consumption; metering; rates, 13, 15
Manchester, N. H.; consumption; metering; rates, 5 seq.
Manganese; o-tolidin test and, 706 seq.
Manganese removal; softening with greensand and, 232
Mannington, W. Va.; typhoid, cross-connections and, 477
Marathon Paper Mills; well, backblowing, 146
Marion, Ill.; financing, 659
water supply, 235, 237
Marshalltown; water works rehabilitation, 419
Maryland; tourist camp supplies, 367
Massachusetts Metropolitan District Commission; consumption; metering; rates, 4 seq.

Mauston, Wis.; wells, 145
Mechanicville, N. Y.; water quality, law suit re, 83
Medford; consumption; metering; rates, 13, 15
Melcroft Coal Co.; mine waste pollution case, 142 seq.
Melrose; consumption; metering; rates, 14 seq.
Mendota Lake; chemical and bacterial variations, 370 seq.
Meter; cost, 509
installation, 514 seq.
iron deposits, 515
life of, 523
maintenance; 104
costs, 515
hard water and, 714
outside box; cost, 514 seq.
ownership, law and, 355
practice, 512 seq.
repairs, charge for, 515
roadway operations, protecting during, 106
specifications, 556 seq.
testing, 512 seq., 517
thawing, charge for, 515
Meter reading; Detroit, Mich., and, 353
Metering; Baltimore, Md., 218
Bay City, Mich., 348
Chicago, Ill., and, 345, 715
consumption and, 3 seq., 270, 344 seq., 509 seq., 523 seq.
cost, 523
Detroit, Mich., 353
East Chicago, Ind., 265
Erie, Pa., 341 seq.
Evanston, Ill., 358
fire services and; 512, 520 seq., 702 seq.
law and, 703 seq.
Gary, Ind., 266
Grand Rapids, Mich., 344 seq.
Jeffersonville, Ind., 269
London, Ont., 509 seq., 523 seq.
New Albany, Ind., 270
Niagara Falls, N. Y., 347
Ohio, 345
opposition to, 75 seq.
statistics, 4 seq., 12 seq.
waste and, 218
water use, proper, restriction and, 343
Wheeling, W. Va., 345
Windsor, Ont., 525
Methyl red test; correlation with V. P. reaction, 164
Michigan; highway supplies, 367
iodine and goiter, 223
iodized salt, 222
pipe on private property, ownership, 355
Michigan Lake; chemical and bacterial variations, 381 seq.
water quality, 717
Michigan State Board of Health; iodine survey, 223
Microscopic organisms; filter clogging and, 45
storage and, 63
taste and odor and, 718
see Algae
Milan, Mo.; filtration, 281
Milford, Mass.; consumption; metering; rates, 14
Milton, Mass.; consumption; metering; rates, 14 seq.
Milwaukee, Wis.; consumption; metering; rates, 4 seq.
pumps, vertical triple expansion, 451
typhoid, cross-connections and, 477
Mine waste; pollution, Melcroft Coal Company case, 142 seq.
treatment, 143
Mineral matter; taste and, 235
Minneapolis, Minn.; consumption; metering rates, 4 seq.
Minnesota; cross-connections, regulations, 479
State Board of Health, highway supplies and, 365
Mississippi River; B. coli content, 281
Missouri; bond issue, majority required; bonding limit, 285
fire protection rating, 284 seq.
highway supplies, 367
water supply conditions, 279 seq.
Missouri Conference on Water Purification; meeting, 281 seq.
Missouri Fire Inspection Bureau; ratings, 284 seq.
Missouri River; B. coli content, 281
chemical treatment, laboratory control, 419
Missouri State Board of Health; ground water, sanitary hazards, 283
Missouri Conference and, 281 seq.
sanitary engineering service, 282
wells, deep drilled, specifications, 284 seq.
Moberly, Mo.; filtration, 281
Monette, Mo.; typhoid; water supply, 284
Monona Lake; 370
chemical and bacterial variations, 378 seq.

Montecito County Water District, Cal.; Santa Barbara and, 404 seq.
Montreal, Que.; filtration; double, 665
rapid fine sand, 663 seq.
slow sand, washing, Blaisdell, 666 seq.
Morenci Water Company; fire protection charge, law and, 704
Morris Machine Works; pump installation, 244
Mosquito; Gambusia affinis and, 36
Spirogyra and, 35
see Anopholes
Mota well; description, 146
Mound City, Ill.; water supply, 237
Mount Holly, N. C.; filters, air-binding, 50 seq.
Mount Holly Water Company; water quality, law suit re, 83
Mountain Water Supply Company; mine waste pollution case, 142 seq.
Mueller meter tester; 514
Muscatine, Ia.; intake, sand and, 466

Nahant, Mass.; consumption; metering; rates, 14 seq.
Napoleon, O.; plant control, 140
National Board of Fire Underwriters; check valves, 475 seq.
hydrant spacing, 225 seq.
National Water Main Cleaning Company; Orlando, Fla., and, 249
Neva River, Russia; denitrification, 370
New Albany, Ind.; metering, 270
night flow, 269 seq.
New Bedford, Mass.; consumption; metering; rates, 4 seq.
cross-connections, experience with, 478
New Braunfels, Tex.; water supply, 161
New Britain, Conn.; main extension financing, 259
New England Water Works Association; cast-iron pipe standardization, 412 seq.
consumption, classification of, 6
meter specifications, 556 seq.
New London; wells, 146
New Mexico; highway supplies, 367
municipal water bonds, 690 seq.
State Department of Health, water supply and, 719
New Orleans, La.; consumption; metering; rates, 12
pipe, carbonate films and, 628
New York City; consumption, 9, 15
copper sulfate treatment, residual copper, 650 seq.
metering; 3, 15
fire services, law and, 704
rates, 9, 15
New York State Department of Health; cross-connections, regulations, 415 seq.
sewage chlorination, chlorine tests and, 391 seq.
tannery waste pollution and, 337 seq.
Newark; main sterilization, 57
Newark, N. J.; consumption; metering; rates, 4 seq.
Newburg, N. Y.; typhoid, cross-connections and, 477
Newman (W. J.) Company; Evanston, Ill., and, 364
Niagara Falls, N. Y.; metering and consumption, 347
Niagara River; pollution, 489
Niles, O.; plant control, 140
Nitrates; *see* Nitrogen as nitrates
Nitrification; in lake waters, 371 seq.
rate in water, determination, 372
in sea waters, 369
temperature and, 369, 377
Nitro, W. Va.; typhoid, cross-connections and, 477
Nitrogen as ammonia; seasonal variations, 369 seq.
Nitrogen as nitrates; determination, 169 seq.
seasonal variations, 369 seq.
North Bessemer; *see* Suburban Water Company
North Carolina Section; stream gaging committee, report, 40 seq.
North Carolina State Department of Conservation; stream gaging and, 40 seq.
North Chicago, Ill.; water supply, 236 seq.
Norwood Engineering Co.; Evanston, Ill., and, 364
Norwood Filter Company; Mount Holly and, 50

Oakland, Cal.; cross-connections, experience with, 478
see East Bay Water Company
Oakmont, Pa.; *see* Suburban Water Company
Ohio; cross-connections, regulations, 479
State Board of Health; consumption and metering, 345
highway supplies and, 366

purification plant control, 137 seq.
water treatment, 137 seq.
Ohio Conference on Water Purification; organization, objects and results, 138 seq.
Ohio State Hospital; purification plant control, 140
Ohio Valley Water Company; zeolite softening, 227 seq.
Omaha Metropolitan Utilities District; main laying, 129 seq.
supervisors, school for, 135 seq.
Oneida, N. Y.; water supply, 418
Ontario; water supplies of, 532
wells, logs of drilled, 542
Ontario Provincial Board of Health; water supply, authority re, 534
Organic matter; softening with lime and iron sulfate and, 156
Orientation; temperature and, 631
Orillia, Ont.; pumping station, 455 seq.
Orlando, Fla.; main cleaning, 249, 251
pressure, 249, 251
sewage disposal, 240
water and light plant, 238 seq.
water quality, 246 seq.
Orlando Utilities Commission; organization, 239, 250 seq.
Ortho-tolidin; see Tolidin
Oscillatoria; characteristics; copper sulfate treatment, 502 seq.
Ottawa, Ia.; fire service charge, law and, 704
Owen Sound, Ont.; financing; hydrant charge, 522
rates, 521
water supply system, 521 seq.
Oxygen demand; stream studies and, 419
Oxygen dissolved; coagulation basin, foaming and, 43 seq.
corrosiveness and, 272 seq., 544, 599 seq.
depletion, seasonal variations, 370 seq.
filters; air-binding and, 43 seq.
stream studies and, 419
sugar wastes and, 293 seq.

Painesville, O., plant supervision, 140
Parana River; water quality, 638
Paris, Mo.; water supply, 281
Pasadena, Cal.; California Railroad Commission and, 66
Peabody, Mass.; consumption, 219
drought, emergency measures, 219 seq.
Pearse, Greeley & Hansen; Evanston Ill., and, 364
Pediastrum; characteristics, 500
Penn Township; *see* Suburban Water Company
Pennsylvania; cross-connections, regulations, 479 seq.
highway supplies, 367
meter and pipe on private property, ownership and, 355
Pennsylvania Railroad Company; Melcroft Coal Company case, 142 seq.
Pennsylvania State Department of Health; tannery waste pollution, interstate, and, 337 seq.
Pennsylvania Tannery Waste Disposal Committee; studies, 339
Phenol; chlorobenzol waste and, 292 seq.
decomposition, bacterial, 297
gas works ammonia liquor and, 296
wood distillation waste and, 295
see Chlorination
Philadelphia, Pa.; cross-connections, regulations, 479
filters, efficiency and sand data, 672
H-ion determinations, 27
main relocation, Broad St., 288 seq.
typhoid, cross-connections and, 477
Piedmont, Cal.; typhoid, cross-connections and, 477
Pierce City, Mo.; typhoid, 282
Pike; Gambusia affinis and, 36
Pinole, Cal.; cross-connections, experience with, 478
Pipe; friction in, 716
laying of, 711
see Main; Services
Pipe, brass; corrosion, resistance to, 618 seq.
flow in, 655
Pipe, cast-iron; cement, lining with, 685 seq.
corrosion; cement lining and, 688 seq.
cleaning and, 628 seq.
de Lavaud, earthquake and, 406
flow in, 655
laying of, 129 seq.
life of, 291, 632
standardization, committee, 412 seq.
see Pipe, iron
Pipe, cement-lined; corrosion and damage, resistance to, 688 seq.

deterioration; 620 seq.
sulfates and, 620
lining centrifugally; 685 seq.
cost, 688
Pipe, coatings; asphaltic, centrifugal application, 689
see Corrosiveness; Pipe, cement-lined; Pipe, galvanized
Pipe, concrete; repairing, 407
Pipe, copper; corrosion, resistance to, 618 seq.
see Services
Pipe, galvanized; *see* Pipe, iron; Zinc
Pipe, iron; corrosion; carrying capacity and, 271
loss by, estimated, 598
prevention, economy of, 632 seq.
galvanized, life of, 625, 632
see Corrosiveness; Iron Corrosion
Pipe, cast-iron; Pipe, wrought-iron
Pipe, lead; *see* Services
Pipe, steel; cement, lining with, 685 seq.
corrosion, cement lining and, 688 seq.
see Corrosiveness
Pipe, wrought-iron; flow in, 655
see Pipe, iron
Pitting; *see* Iron corrosion
Pittsburgh, Pa.; services, charge for, 355
Plum Township; *see* Suburban Water Company
Plumbing; 716
brass fixtures, waste and, 521
service complaints and, 486 seq.
staining and, prevention, 624 seq.
Pollution; iodine content and, 223
Pollution, industrial wastes; chlorobenzol, chlorination taste and, 292 seq.
corn canning and, 527 seq.
dairying and, 527 seq.
gas works and, 295 seq.
mines and, Melcroft case, 142 seq.
sugar waste, oxygen depletion and, 293 seq.
tannery and, 336 seq.
wood distillation and, 295 seq.
Pollution, stream; Illinois and, 717
interstate, 335 seq.
oxygen demand and; oxygen dissolved and, 419
sewage disposal and, 717
Pollution, watershed protection; 719
Pond-Felt; *see* Vaucheria
Population; future, estimating, 2
growth, consumption and, 1 seq.
Port Clinton, O.; plant control, 140
Port Washington; sewage chlorination, 399
Potosi, Mo.; typhoid, 284
Power Specialty Company; superheater, 243
Prechlorination; Davenport, Ia., and, 253
Pressure; complaints, plumbing and, 486
consumption and, 518, 523
main cleaning and, 251
practice, 118, 249
Priester Construction Company; Davenport plant and, 255
Providence, R. I.; consumption; metering; rates, 4 seq.
Public relations; 711
complaints and, 78
office administration and, 351 seq.
utilities and, 72 seq.
Pump; filters, air-binding and, 49 seq.
motor drive; motor capacity and, 454 seq.
overloading and, 454
power factor and, 455 seq.
see Well pumping
Pump, air-lift; 716
Pump, centrifugal; efficiency; 452
speed and, 456
high speed, 453, 457
low-head, 453, 457
primer, Apco, 647 seq.
single stage, 452
suction lift, 454, 457
Pump, reciprocating; efficiency, 451 seq.
vertical triple expansion, 451 seq.
Pumping station; Chicago, Ill., 715
design, 455 seq.
drive; electric; 716
automatic operation, 457 seq.
steam; auxiliaries for, 418
standby; losses, 453 seq.
unit, internal combustion engines and, 454
peak demand, storage and, 109 seq.
situation, 455
Purification; loading, B. coli limit, 535
Ohio and, 139 seq.
small cities and, 549 seq.
supervision, technical, 139 seq., 683
see Chlorination; Coagulation; Filtration; etc.

Quincy, Ill.; reservoir, 716
Quincy, Mass.; consumption; metering; rates, 13, 15

Racine, Wis.; water works rehabilitation, 716
Railroad supplies; foaming; alkaline carbonates and sulfates and, 634, 636
anti-foaming compound, 636, 639
blow-off and, 636, 639
"light water" and, 636
salt concentration and, 639
treatment; boiler failures and, 635, 637
control, 638
economy of, 635 seq.
see Boiler; Softening
Rainfall; evaporation and percolation loss, 533
forest and, 542
incidence of, 531, 539
Raleigh, N. C.; filters, air-binding, 46
Rates; California Railroad Commission and, 65 seq., 75
collection, 353
comparing, 522
consumption and, 1 seq., 510 seq.
Erie, Pa., 341 seq.
lawn sprinkler, battery type, and, 77
London, Ont., 510 seq., 523
mixed, 76
Owen Sound, Ont., 521
service charge, 511, 519, 522 seq.
statistics, 4 seq., 12 seq.
Walkerville Water Company, 525
waste and, 347
see Financing
Ravenna, O.; plant supervision, 140
Reading, Pa.; main extension financing, 258 seq.
Recarbonation; *see* Carbonation
Records; cost, 79
operating, 470
Red water troubles; *see* Corrosiveness; Iron corrosion
Reedy Fork Creek; water quality, 62 seq.
Reservoir; balancing, design, 105 115 seq., 118 seq.
concrete-lined; 492 seq.
cost, 128, 494
design and construction, 118 seq.
Malaria mosquito and, 35 seq.
overflow, altitude valve and, 494
regulations, 37 seq.
sea gulls and, 120 seq.
shallow, filter air-binding and, 46
stripping; color and, 63
mosquitoes and, 36 seq.
see Storage
Revere, Mass.; consumption; metering; rates, 13, 15
Rhode Island; highway supplies, 367
Richmond, Cal.; *see* East Bay Water Company
Rivularia; characteristics, 503
Rochester, N. Y.; consumption; metering; rates, 4 seq.
cross-connections, experience, 478
sodium iodide treatment, 222, 409, 411
Rockaway, N. J.; typhoid, cross-connections and, 477
Rockford, Ill.; cross-connections, experience, 700
water supply, 236
Rocky Ford, Colo.; filtration, 719
Rocky Mountain Section; organization meeting,717 seq.
Rosario, Argentine; *see* Consolidated Water Works Company

Sacramento, Cal.; cross-connections, experience, 478
reservoir, 120
Saginaw Bay; industrial waste pollution, 292 seq.
Saginaw River; bacterial activity, 297
industrial waste pollution, 292 seq.
Saint Catharines, Ont.; rainfall, 541
Saint Joseph, Mo.; water supply, 280
Saint Louis, Mo.; consumption, 15
filtration, 281
fire protection charge, law and, 704
metering, 15
rates, 15
water supply; 279 seq.
Saint Paul, Minn.; consumption; metering; rates, 4 seq.
softening, 152 seq.
typhoid, cross-connections and, 477
Salem, Mass.; sprinkler connection, broken, waste and, 701
Salisbury, Mo.; iron removal, 282
Sampling; apparatus, 370
San Antonio, Tex.; consumption; metering; rates, 13
water supply, 161
San Antonio River; flow, 160
San Felipe Spring; 162
flow, 160
San Francisco, Cal.; softening, fuel saving and, 156
see Spring Valley Water Company
San Jose, Cal.; reservoir, 120
San Marcos, Tex.; water supply, 161
San Marcos River; flow, 160
San Pedro, Cal.; cross-connections, experience, 478
San Pedro River; flow, 160
Sand; *see* Filter sand

Sandusky, O.; plant control, 140
Santa Barbara, Cal.; water system, earthquake and, 404 seq.
Santa Cruz, Cal.; water system, 103
Santaquin, Utah; goiter, iodine and, 223
Saugerties, N. Y.; typhoid, cross-connections and, 477
Sault Ste. Marie, Mich.; sodium iodide treatment, 222
School; water waste, metering and, 348
Schuette and Koerting; oil burners, 243
Sea Gulls; reservoirs and, 120 seq.
Sea water; nitrification and denitrification, 369 seq.
Sebring, O.; plant control, 140
Sectional Committee on Standard Specifications for Cast-Iron Pipe; organization, 412 seq.
Sedalia, Mo.; water supply, 280 seq.
Sedgwick (W. T.) Memorial; organization, etc., 415
Sedimentation; *see* Coagulation basin; Settling basin
Seismic activity; *see* Earthquake
Services; charges for, 354 seq., 505, 520
  copper, cost, 508, 519
  fire; bleeding from, 700 seq.
    metering of; 512, 520 seq., 702 seq.
      law and, 703 seq.
    size restriction, 701 seq.
  installation; 103
    in advance of pavement, 505, 524 seq.
    pushing and, 505, 507
  lead, cost, 505, 508, 519
  practice, 354, 356, 505 seq., 515 seq.
  on private property, ownership and, 353 seq.
  roadway operations, protecting and, 106
  size, 518 seq.
Settling basin; improvement, Davenport, Ia., 252 seq.
  see Coagulation basin
Sewage treatment; chlorination; control, excess chlorine and, 391 seq.
  efficiency, 391 seq.
  direct oxidation, pH control, 33
  stream pollution and, 717
Shelbina, Mo.; water supply, 281
Shelbyville, Ind.; cross-connections and, 702
Sigourney; water supply, 551 seq.
Snohomish River; water quality, 81
Soap; waste, softening and, 23, 155
Society affairs; California Section meeting, 103 seq.
  Central States Section meeting, 712 seq.
  Four-States Section meeting, 417
  Illinois Section meeting, 714 seq.
  Indiana Section meeting, 709 seq.
  Iowa Section meeting, 417 seq.
  Rocky Mountain Section meeting, 717 seq.
Soda ash treatment; corrosion and, 274, 625 seq.
  cost, 274
  H-ion concentration and, 625
Sodium hydroxide treatment; corrosion and, 274, 626
  cost, 274
Sodium hypochlorite; filter sterilization with, 56
  main sterilization with, 55
  see D. K. solution; Hypochlorite
Sodium iodide; Br. Pharmacopoeia dose, 411
Sodium iodide treatment; in Akron schools, 411
  English comments, 409 seq.
  health and, 409 seq.
  Rochester, N. Y., and, 222, 409, 411
  Sault Ste. Marie, Mich., 222
Sodium silicate treatment; corrosion and, 630
Sodium sulfate; boiler foaming and, 636
Sodium thiosulfate; B. coli and, 395, 398
Softening; base exchange; greensand;
  advantages, 233
    cost, 232
    Crenothrix removal, 232
    economy of, 227
    manganese removal, 232
  economics of, 154 seq.
  fuel saving and, 156
  health and, 152 seq.
  hot process, 419
  lime and iron sulfate; after-precipitation, recarbonation, and, 154
    algae and, 156
    chlorination and, 156
    corrosiveness and, 157
    cost, 155
    filtration and, 156
    organic matter removal, 156
  lime-soda; advantages, 233
    cost, 232
    limits of, 233
  soap saving and, 155

taste and, 153 seq.
see Calcium carbonate; Carbonation; Greensand; Hardness; Railroad supplies
Soil; coli-aerogenes group in, 641 seq.
Somerville, Mass.; consumption; metering; rates, 13, 15
South Carolina State Department of Health; impounded waters, regulations, 37
Spirogyra; characteristics, 501
copper sulfate treatment and, 501, 504
mosquitoes and, 35
Spring; capacity, increasing, 148
fissure, colon bacteria in, 158 seq.
pollution, underground, 283
Spring Valley Water Company; California Railroad Commission and, 66
consumption, 5 seq., 486
metering, 5 seq., 486
rates, 5 seq.
reservoirs, 118 seq.
service complaints, plumbing and, 486 seq.
Springfield, Mass.; consumption; metering; rates, 4 seq.
Springfield, Mo.; water supply, 280 seq.
Springfield, O.; typhoid, cross-connections and, 477
Springfield Boiler Company; installation, 243
Sprinkler system; number opening during fires, data on, 701
see Fire protection, private
Standpipe; design, 105
State Sanitary Engineers' Conference; ground water, sanitary hazards, 283 seq.
Sterilization; *see* Chlorination; Iodine treatment
Stoneham, Mass.; consumption; metering; rates, 14 seq.
Storage; peak demand and, 109 seq.
water quality and, 63
see Reservoir
Stratification; depth and, 370
Stream; flow, proportion available, 533
gaging, committee report, 40 seq.
see Pollution, stream
Struthers, O.; plant control, 140
Suburban Water Company; reservoir, re-lining, 492 seq.
Sugar; waste; chlorination and, 293
oxygen depletion and, 293 seq.
Sulfates; boiler foaming and, 634
concrete deterioration and, 620
pitting and, 607
see Sodium sulfate
Sun Prairie, Wis.; wells, 145
Suspended matter; *see* Turbidity
Swampscott, Mass.; consumption; metering; rates, 14 seq.
Swimming pool; chlorination, residual chlorine control, 386 seq.
cross-connections and, 594
Switzerland; goiter, iodine and, 222, 411
Synura; copper sulfate treatment and, 650

Tallahassee Power Company; new mains, pollution and, 53
sterilization with hypochlorite, 60 seq.
Tampa Water Company; private fire protection charge, law and, 704
Tannery; waste; disposal studies, 338 seq.
pollution, 336 seq.
Taste and Odor;
hardness and, 153 seq.
microscopic organisms and, 496 seq., 718
mineral matter and, 235
see Chlorination
Taunton, Mass.; consumption; metering; rates, 13
Tecumseh, Ont.; water supply, 540
Temperature; corrosiveness and, 603, 630 seq.
orientation and, 631
Terre Haute, Ind.; fire flow, 699 seq.
fire protection charge, legality of, 703
Texas; fissure springs, B. coli in, 158 seq.
tourist camp supplies, 367
Thomasville, N. C.; filters, air-binding, 49
Threads; specifications, American Briggs, 557
Thyroidism; *see* Goiter
Tiffin, O.; plant supervision, 140
Tioga River; tannery waste pollution 336 seq.
Tittabawassee River; industrial waste pollution, 292 seq.
Toledo, O.; consumption; metering; rates, 4 seq.
plant control, 140
o-Tolidin; colors with chlorine, pH and, 707
see Water analysis
Tomah, Wis.; wells, 145
Toronto, Ohio; plant control, 140

Toronto, Ont.; meters, testing, 517
pumps, reciprocating, 451 seq.
services, 515 seq.
typhoid, cross-connections and, 477
Torrington Water Co.; water quality, law suit re, 83
Treatment; *see* Aeration; Chlorination; Filtration; Softening; etc.
Trench; backfiller, 130, 133
danger signals, 131 seq.
flushing or tamping, 132
machine, 507
Trenton, Mo.; filtration, 281
Tuberculation; *see* Iron, corrosion
Tunnel; natural, Springfield Mo., 283
Turbidity; amount, permissible, 681 seq.
character, variability; 674 seq.
slow sand filtration and, 676
coagulation, alum dosage and, 23
corrosion and, 606
determination, 697 seq.
storage and, 63
Turbine, steam; size and steam consumption, 453
Typhoid; cross-connections and, 81, 477, 700
epidemics, list of, 477, 700
Monett, Mo., 284
Pierce City, Mo., 282
Potosi, Mo., 285
water-borne, liability for, Everett, Wash., case, 80 seq.
water treatment, discontinuous and, 282
see Disease, intestinal

United States; Department of Interior; Geological Survey; stream gaging, 40 seq., 160
water data and, 402 seq.
water hardness and, 152 seq.
Treasury Department; Public Health Service; Great Lakes Survey, 489
malaria, impounded waters and, 37 seq.
water supplies, municipal, and, 719
water resources, 41, 403
Upper Sandusky, O.; plant control, 140
Utah; goiter, iodine and, 223
tourist camp supplies, 367
Utilities; extensions, law and, in California, 73 seq.
operation at loss, law and, 73
public relations, 72 seq.
revenue, fair return, 69

Valley Park, Mo.; water supply, 281
Valuation; California Railroad Commission and, 65 seq.
Valves; altitude, 494
see Check valve
Van Wert, O.; typhoid, cross-connections and, 477
Vaucheria; characteristics, 501 seq.
Vermillion, O.; plant control, 140
Verona, Pa.; *see* Suburban Water Company
Virginia; highway water supplies, 367
Virginia State Board of Health; impounded waters, regulations, 37
Voges-Proskauer Reaction; correlation with methyl red test, 164
Vulcan; soot blowers, 243

Walkerville Water Company; rates, 525
water supply, 540
Waltham, Mass.; consumption; metering; rates, 5 seq.
Warren, O.; services, 356
Washington, D. C.;
main extension financing, 258 seq.
Washington, State of; cross-connections, regulations, 479
highway supplies, 367
Waste; brass fixtures and, 521
detection, 267 seq.
metering and, 218
rates and, 347
restriction, inspection and, 343
see Consumption
Water; data, need of, 400 seq.
health and, 418
Water analysis; carbon dioxide, 277
chlorine, free; o-tolidin; 391 seq.
apparatus for, 389 seq.
iron and manganese and, 706 seq.
natural waters and, 706 seq.
Nessler tubes vs. bottles, 393 seq.
organic matter and, 393
standards, permanency, 390
temperature and, 393
starch-iodide, 391 seq.
colorimetric, permanent standards, apparatus for, 554 seq.
copper, minute amounts, 652 seq.
H-ion concentration; colorimetric, accuracy, 29 seq.
recording, 22 seq.
tungsten electrode, accuracy, 29 seq.
nitrate reduction, rate, 372

nitrification, rate, 372
nitrogen as nitrates; phenoldisulfonic acid; color match improvement, 169
organic matter and, 169
reduction method, 169 seq.
oxygen dissolved, Winkler method, 372
turbidity, electrical method, 697 seq.
see Sampling
Water, gratuitous; 70 seq., 259
Water measuring; methods, 709
pump strokes, inaccuracy, 266
Water-net; *see* Hydrodictyon
Water quality; hardness, desirable amount, 534
iodine, desirable amount, 223
turbidity, permissible amount, 681 seq.
Water rights; riparian, 533 seq.
Water supply; drought, emergency measure and, 213 seq., 219 seq.
ground water, sub-surface dams and, 149 seq.
highway, placarding, 365 seq.
source; future, provision for, 1
ground vs. surface, 537, 542 seq., 549 seq.
selection, 531 seq.
watersheds, cultivated, foaming and, 46
see Well
Water, unaccounted for; comparing, 268
Gary, Ind., and, 267
reducing, Western New York Water Company, 521
Water works; beautification, 241 seq., 481 seq.
fire department and, 105, 466
health department and, 421, 590 seq.
office administration, 349 seq.
operating costs, Erie, Pa., and Jefferson City, Mo., 346
small town, 716
see Chlorination; Filtration; Financing; Public Relations; Utilities; etc.
Watershed; *see* Pollution, watershed protection; Water supply
Watertown, Mass.; consumption; metering; rates, 13, 15
Watertown, Wis.; well, shooting, 144
Watervliet, N. Y.; typhoid, cross-connections and, 477
Waubesa Lake; chemical and bacterial variations, 381 seq.
Waukegan, Ill.; water supply quality 717
Waupaca, Wis.; well, 148
Wausau; well, back-blowing, 146
Wauseon, O.; plant control, 140
Well; capacity, increasing, 144 seq.
drilled; logs of, 542
specifications, 284 seq.
driven *vs.* tubular, 147
interference, mutual and, 145, 538
Kelly, 546 seq.
"Mota" type, 146
new, locating, 149 seq.
pollution, underground, 283 seq.
pumping; method, capacity and, 150 seq.
mutual interference and, 145
shallow, 716
tubular; *vs.* driven, 147
screens, clogging of, 546 seq.
types, approved, in Illinois, 716
see Ground water
Wellington, O.; plant control, 140
Western New York Water Company; unaccounted for water, 521
Westinghouse; turbo-generator, 244
Wheeler; condenser, 244
Wheeling, W. Va.; metering and consumption, 345
Whitewater; well, capacity, increasing, 144
Willoughby, O.; plant supervision, 140
Wilmette, Ill.; consumption, 359 seq.
Wilmington, N. C.; coagulation basins, foaming in, 42
filters, air-binding, 43
sodium hypochlorite and, 55 seq.
Windsor, Ont.; metering, 525
water supply, 540
Wingra Lake; chemical and bacterial variations, 381, 383
Winner, S. D.; water supply improvements, 546 seq.
Winthrop, Mass.; consumption; metering; rates, 14 seq.
Wisconsin; lakes, ammonia and nitrate content, 369 seq.
Wisconsin Geological and Natural History Survey; Wisconsin lakes and, 370
Wood distillation; waste, phenol and, 295
Woodsfield, O.; plant control, 140
Woonsocket, R. I.; consumption; metering; rates, 5 seq.
Worcester, Mass.; consumption; metering; rates, 4 seq.

Wyoming; municipal water bonds, 690 seq.
Wyoming State Department of Health; water supply, 719

Yonkers, N. Y.; consumption; metering; rates, 5 seq.

Zeolite; *see* Greensand; Softening
Zinc; corrosion; 603, 612 seq.
oxygen dissolved and, 621
protective coating and, 613 seq., 624, 631
temperature and, 630 seq.
solubility, pH and, 615 seq.

AUTHOR INDEX AND NAME REFERENCE

ABSHER, C. W., sterilization of water mains after laying, 52 seq.
ALBERSON, JAS., 420
ALTIERI, 605
ALVORD, J. W., 238 seq.
AMSBARY, F. C., 715
ANDERSON, G. M., 719
ANDERSON, L. M., 104
ANGUS, ROBT. W., the water works pumping station, 451 seq.
ARMSTRONG, KENNETH C., 419
AUSTIN, E. M., 249
AUSTIN, R. N., 456

BABBITT, H. E., 715 seq
BAHRT, G. M., 369, 385
BAIN, JAS., 458
BAIRD, THOMAS, 105
BAKER, L. E., 27
BALL, CHAS. B., 597
BANCROFT, 599 seq.
BANKSON, 347
BARBOUR, FRANK A., 414
BARNUM, EDMUND K., 105
  balancing reservoirs to supplement pump capacity during peak demands, 109 seq.
BARR, WM. M., 23
BATES, C. O., 418 seq.
BATES, H. E., 414
BAUMGARDNER, W. E., 297
BAYLIS, JOHN R., 49
  prevention of corrosion and "red water," 598 seq.
  rapid fine sand filtration—discussion, 673 seq.
  see PARKER, H. C., AND BAYLIS, J. R.
BEARDSLEY, H. M., interstate pollution of streams, 335 seq.
BEECH, F. B., 714
  zeolite softening plant of the Ohio Valley Water Company, 227 seq.
BEIJERNICK, 171, 173
BELL, D. Z., 717
BIGGS, GEO. W., JR., *see* PORTER, H. H., BIGGS, G. W., JR., AND FULLER, G. W.
BIILMANN, 27
BIRDSALL, LEWIS I., 251, 418 seq.
BIRGE, E. A., 385
BLACK, E. B., 419, 421
BLAIR, HOMER O., liability for water-borne disease, 80 seq.
BLAISDELL, HIRAM W., 663 seq.
BLANCHARD, R. K., 556
BLANCHARD, W. S., 364
BLOMQUIST, H. F., 418 seq.
  financial reports of water works operation, 469 seq.
BORUFF, C. S., 391
BRADFORD, F. H., 716
  automatic primers for centrifugal pumps, 647 seq.
BROCKWELL, SHERWOOD, 41
BROOKS, THOMAS, 106
BROSSMAN, CHAS., 709, 711
BROWN, C. D., 539 seq.
BROWN, E. D., 417
BRUSH, WM. W., 414, 417, 556
BUCHANAN, E. B., *see* BUCHANAN, E. B., AND PERKINS, R. G.
BUCHANAN, E. B., AND PERKINS, R. G., residual chlorine and the bacterial content of swimming pools, 386 seq.
BUCHANAN, E. V., 457, 460, 542 seq.
  services and meters, 505 seq.
BUCHANAN, JOHN H., 419 seq.
  the pollution of water supplies by wastes from canneries and dairies in Iowa, 527 seq.
BUGBEE, PERCY, 709
BURDICK, CHAS. B., 238 seq.
BURGESS, PHILLIP, 137
BURKE, GEO. W., nitrate determinations, 169 seq.
BURT, JOHN, 104
BUSWELL, A. M., 391, 419 seq., 639, 717
BUTCHER, B. H., use of chinic acid in the differentiation of the colon-aerogenes groups, 171 seq.

CALVERT, C. K., 711
CAMPBELL, A. M., 414
CATLETT, GEO. F., 22, 44 seq., 56 seq.
CHATIN, 222
CHESTER, JOHN N., 345 seq., 353 seq., 714
CHILDS, 107
CHIPMAN, WILLIS, 510
CHURCH, S. R., 414

Clark, Frank P., 105
Clark, Wm. M., 22, 164
Claussen, A. W., 414
Clow, J. B., 414
Clow, Kent S., 414
Cohen, B., 165 seq.
Cole, A. W., 710
Collins, W. D., 152, 418, 420
Conard, W. R., 414
Coughlan, R. E., 716
  the water supply of the Chicago and Northwestern Railway, 634 seq.
Cox, C. R., 338
Cramer, W. S., 701 seq.
Crampton, J., 297
Cranborne, Leslie, 104, 106
Crosier, Chas. L., re-lining the Verona reservoir, 492 seq.
Czizek, M. H., 421

Danielson, Frank G., 717
Dannerth, C. A., 26
Davenport, A., 385
Davis, Carlton E., 417
Dawson, 29
DeBerrard, W. W., 421
Diedrich, P., 104, 106
Dill, Howard A., 710 seq.
Dittoe, W. H., water treatment in Ohio, 137 seq.
Dodworth, W. K., 106
Domogalla, B. P., *see* Domogalla, B. P., Fred, E. B., and Peterson, W. H.
Domogalla, B. P., Fred, E. B., and Peterson, W. H., seasonal variations in the ammonia and nitrate content of lake waters, 369 seq.
Douglas, C. E., 417
Drake, Chester F., 713
Drew, G. H., 369, 384 seq.
Dudley, H. M., 105
Dunham, 376
Durbin, W. H., 711

Eddy, Harrison P., 175, 177
Eldridge, E. F., 223
Elliott, G. A., 104
Ellms, J. W., 713 seq.
  water supply and sewage disposal of the Great Lakes Cities, 489 seq.
  rapid fine sand filtration—discussion, 681 seq.
Elmes, Cecil F., 238
Emerson, C. A., Jr., 714
  progress of the Melcroft case, 142 seq.
Endris, J. O., 268 seq.
Enger, M. L., 715 seq.
Enslow, Linn H., 392
Evans, John, 483 seq.

Fagg, J. H., 104
Fairchild, I. J., 414
Ferguson, Harry F., 716 seq.
Field, Frederick E., rapid fine sand filtration—discussion, 663 seq.
Finch, Lewis S., 710 seq.
Fisher, Geo., 518
Flaa, I. E., 105
  design and construction of concrete-lined distributing reservoirs, 118 seq.
Ford, A. M., 415
Forsberg, Ole, reaction of orthotolidine with surface waters, 706 seq.
Forstall, Walton, 413
Fox, Paul S., 718 seq.
Francis, J. B., 655
Fred, E. B., *see* Domogalla, B. P., Fred, E. B., and Peterson, W. H.
Freeeman, John R., 654 seq.
Fulkman, John A., 494
Fuller, Geo. W., 48, 176, 357, 421
  see Porter, H. H., Biggs, G. W., Jr., and Fuller, G. W.

Gallaher, W. U., 714
Garvin, A. G., 494
Gelston, W. R., 716
Gensheimer. Geo. C., 346, 348, 713
Georgia, F. R., permanent standards for water analysis, 554 seq.
Gettrust, J. S., 276
Gibson, Jas. E., 59, 414
Giesey, J. K., 716
Gilkison, G. F., 418 seq.
Gillett, Omer R., 719
Goble, Wm. F., 106
Goedike, F. B., 517 seq.
Goethals, General, 495
Goldsmith, Clarence, 701, 710
Goodell, John M., obituary of Leonard Metcalf, 174 seq.
Gore, Wm. 458 seq.
  supply, intakes and storage, 531 seq.
Gorman, Arthur E., 639, 717
  cross-connections in Chicago, 587 seq.
Goudey, R. F., the menace of cross-connections in a public water supply, 472 seq.
Greeley, Samuel A., 364

GREEN, PAUL E., 716
water certificates to finance water supply plants in Illinois, 658 seq.
GREENFIELD, MYRTLE, 168
GRISWOLD, DON M., 418 seq.
GROBBEL, D. C., 713 seq.
office administration of city water department, 349 seq.
GROSS, CARL D., 716
GROSS, D. D., 719
GROVER, N. C., 418, 420
the need for data relating to water, 400 seq.
VAN GUNDY, C. P., 414
GURNEY, CHAS. E., 175
GWILLIM, E. C., 717
GWINN, DOW R., the business side of private fire protection, 699 seq.

HABERMEYER, G. C., 419 seq., 716
ground water resources of Illinois, 234 seq.
HALE, FRANK E., *see* HALE, F. E., AND MUER, H. F.
HALE, F. E., AND MUER, H. F., copper in the distribution system following watershed treatment, 650 seq.
HAMMERSTROM, W. G., 414
HANLEY, GEO. W., 717
HANLEY, J. P., 418 seq., 717
HANNAN, FRANK, 22
HANSEN, PAUL, 639, 716
additions to the Evanston, Ill., filter plant, 357 seq.
HARPER, D. W., 713
the installation of filters in Erie, 341 seq.
HARRINGTON, 670
HARRISON, LOUIS B., 348
chlorophenol-like tastes in Bay City's filtered water supply, 292 seq.
HATFIELD, WM. D., 22, 717
HATHAWAY, 223
HATT, W. K., 710
HAWKINS, H. C., 417
HAWLEY, W. C., 224, 414
HAYS, C. D., 417 seq.
HAZEN, ALLEN, flow of water in pipes—a review, 654 seq.
rapid fine sand filtration—discussion, 683 seq.
HEDGEPETH, L. L., 49
HENDERSON, CHAS. R., 418 seq.
keeping the water works working, 461 seq.
HERSCHEL, CLEMENS, 526
HETZER, MENTOR, 713
HEZZELWOOD, L. L., 419
HILL, NICHOLAS S., JR., 104
HILL, ROBT. T., 158 seq.
HINMAN, JACK J., JR., 417 seq.
HITCHENS, A. P., 222
HODGMAN, BURT B., 57
HODKINSON, T., 519
HOLADAY, K., 638
HOLBROOK, ROYAL H., 417 seq.
HOLDERBY, JESS M., 419 seq.
HOLMQUIST, C. A., 337, 339
HOOVER, SECRETARY HERBERT, 401
HOPKINS, D. P., 415
HOPKINS, EDWARD S., 678
HOPKINS, P. F., 418 seq.
HOUSTON, ELINOR R., 165
HOWSON, L. R., 238 seq., 251, 638, 716
HUFFS, N. L., algae in water supplies, 496 seq.
HUNTER, H. G., 457
HUNTER, HAROLD F., 716
HURTY, JOHN N., 712
HUY, HARRY F., 347, 354 seq., 417, 521, 713

JACK, G. R., 520
JACKSON, C. B., 104
JENKINS, E. J., 264
JENSEN, J. C., 417 seq.
JONES, E. G., 369, 385
JORDON, FRANK C., 258 seq., 709, 711
JORDON, H. E., 270
JUDAY, C., 385

KEELER, E. A., 25
KEELER, H. E., 716
KEITH, J. CLARK, 523 seq.
KELLERMANN, K., 369, 384 seq.
KELLY, J. W., 710
KENNISON, KARL R., 654, 657
KEPNER, DANA E., 717, 719
KERRICK, W. O., 103, 106
KETCHUM, M. S., 716
KILPATRICK, 670
KIMBALL, 222
KIMBALL, W. H., improvement of settling basins, 252 seq.
KING, F. H., 421
the spacing of fire hydrants, 224 seq.
KING, WM. F., 702, 712
KIRCHOFFER, W. G., increasing the capacity of ground water supplies, 144 seq.
KIVELL, W. A., 419
KLAUS, FRED J., 104
KNAPP, W. A., 711
KNIGHT, NICHOLAS, 418, 420
KNOUSE, HOMER V., 419 seq.
laying cast-iron mains: organization and methods, 129 seq.
KNOWLES, CLARENCE R., 414, 417 seq., 638 640, 717

KOLTHOFF, I. M., 29
KOSER, STEWART A., 171, 173, 717
the coli-aerogenes group in soil, 641 seq.
KUHN, W. S., 298

LAFRENIÈRE, THÉO. J., 540
LAMER, V. K., 27
LASKER, 46
LAUX, PAUL C., 418, 420
the causes and prevention of red water, 271 seq.
LAWLOR, FRANK, 417 seq.
LEA, W. S., 456 seq.
LEDOUX, J. W., 274
LEGREE, 57 seq.
LEPRINCE, J. A., the relation of storage water supply lakes to malaria, 35 seq.
LEVINE, MAX, 163, 168, 417 seq., 646
LEWIS, I. M., colon bacteria in some fissure springs of the Balcones Fault Zone, 158 seq.
LILLY, H. A., 53, 55
sterilization with freshly prepared hypochlorite, 60 seq.
LIPMAN, C. B., 369, 384 seq.
LITTLE, BEEKMAN C., 174, 417, 709, 713, 714, 716
VAN LOAN, SETH M., 417, 556
Water Bureau interests during the construction of the North Broad Street Subway, Philadelphia, 288 seq.
rapid fine sand filtration—discussion, 671 seq.
LOGAN, C. S., 53
LOVELL, A. P., 103 seq.
LOWTHER, BURTON, 718
LUBS, H. A., 164
LUCE, A. T., 417 seq.
LUSCOMBE, WM., 265 seq.

MCCALEB, 417
MCCLENDON, J. F., the prevalence of simple goiter and its relation to iodine content of water and foods, 222 seq.
MCCONNELL, EARLE G., 46 seq.
MCCOUGHERN, J. C., 104
MCDONALD, FRED K., 106
MCEVOY, J. W., 417 seq.
MCFAUL, W. L., 455, 460
MCINNES, F. A., 414, 701
MCKELVEY, S. R., 718
MCLAUGHLIN, A. J., 489, 709
MCRAE, J. P., 456
MABEE, W. C., 710
MACKALL, M. R., 105
the California Railroad Commission and the water works man, 64 seq.
MAFFITT, M'KEAN, 41, 53 seq.
MAGESTADT, PAUL E., 104
MAHLIE, W. S., sampling of filter sand, 256 seq.
MARINE, 222
MARTINDALE, R. W., 106
MATTESON, VICTOR A., 243, 716
MATHEWS, W. W., the municipal water and light plant at Orlando, Fla., 238 seq.
MAURY, DABNEY H., 238
MAXWELL, D. H., 716
MENDELSOHN, ISADOR W., 719
MEREDITH, 46
MERRITT, 261
METCALF, LEONARD, 224, 523 seq.
effect of water rates and growth in population upon per capita consumption, 1 seq.
obituary, 174 seq.
MILLER, I. L., 711
MILLS, HIRAM F., flow of water in pipes, 654 seq.
MINDER, L., 369, 385
MITCHELL, WM. C., 718
MOHLMAN, F. W., 717
MOIR, DONALD, applying cement lining by centrifugal means to cast-iron and steel pipes, 685 seq.
MOLDENKE, RICHARD, 414
MOLIS, WM., 417 seq., 466
MOORE, JOHN W., 710 seq.
MOORE, W. D., 414
MORGAN, J. H., 40
MORRIS, SAMUEL B., 104 seq.
MORSE, H. S., 709, 711
MOWRY, C. W., 414
MUER, HENRY F., *see* HALE, F. E., and MUER, H. F.
MULCAHY, CHAS., 597

NETSCHAFF, N., 370, 385
NEWMAN, W. J., 364
NEWSOM, REEVES J., 219 seq.
NORCOM, GEO. D., 22, 42 seq., 54 seq.
NUNN, HERBERT, 405

OGGLE, CICERO, 718
OLIPHANT, JOHN, 716
OSTERHOUT, W. J. V., 415

PALMER, C. S., 262
PARKER, HENRY C., *see* PARKER, H. C., AND BAYLIS, J. R.
PARKER, H. C., and BAYLIS, J. R., recording the hydrogen-ion concentration of potable water, 22 seq.
PATTERSON, T. C., 50

PEARSE, 364
PEARSE, LANGDON, 357
PEDERSEN, HANS V., 419
water purification for small cities, 549 seq.
PEQUEGNAT, MARCEL, 520
PERKINS, R. G., *see* BUCHANAN, E. B., and PERKINS, R. G.
PERRY, V. E., 106
plumbing and service complaints, 486 seq.
PETERSON, W. H., *see* DOMOGALLA, B. P., FRED, E. B., AND PETERSON, W. H.
PHILLIPS, ASA E., 176
PHILLIPS, C. N., 719
financing water works projects, 690 seq.
PIRNIE, MALCOLM, 23
PORTER, D. P., 718
PORTER, H. HOBART, *see* PORTER, H. H., BIGGS, G. W., JR., AND FULLER, G. W.
PORTER, H. H., BIGGS, G. W., JR., AND FULLER, G. W., obituary of JESSE H. PURDY, 298 seq.
POTTER, A. W., 709
PRACY, GEO. W., 103
PRATCHNER, 106
PRATT, C. J., 517, 521 seq.
PRAY, JOHN W., 417
PRESCOTT, S. C., 646
PRICE, W. I., 262
PRINCE, GEO. T., improvements to the water supply of Winner, S. D., 546 seq.
PROCTOR, E. M., 518 seq.
PRUGH, JUDY I., 104 seq.
PURDY, JESSE H., obituary, 298 seq.
PURDY, W. C., 710
PUTNAM, GEO. W., 419
water supply conditions in Missouri, 279 seq.

RADEBAUGH, G. H., 715
RAMSAY, WM., 544
RANDLETT, FRED M., 104
RANKIN, R. S., 716
RATHBUN, W. S., 717 seq.
RAWLINGS, I. D., 717
READ, GEO., 103
REED, D. A., financing water main installations, 258 seq.
RIDGEWAY, W. C., 711
RIPPLE, O. J., 718
ROBINSON, B. J., 104
ROGERS, L. A., 166, 168
ROOS, C. M., 236
ROUTLEDGE, C. G., 515 seq.
RUCHHOFT, C. C., 717
RUE, J. A., 716
RUSSEL, J. C., 369, 385
RUSSELL, 599, 605
RUSSELL, N. F. S., 415
RYLAND, 104

SAVAGE, B. B., 297
SAVILLE, CHAS. M., 556
SAVILLE, THORNDIKE, 271
SCHAUT, GEO. G., 107
SCHNEIDER, W. J., 467
SCOTT, E. A., 711
SCOTT, LEROY H., precise turbidity, readings by electrical methods, 697 seq.
SEDGWICK, G. E., 104
SEDGWICK, WM. THOMPSON, 415
SHELLMAN, B. BROWN, 415
SHERMAN, CHAS. W., 414
specifications for cold water meters, 556 seq.
SHOEMAKER, GEO. E., 421
SIEMS, V. BERNARD, 417
Baltimore City Water Department meets emergency during drought of June, 1925, 213 seq.
SIMPSON, C. C., 414
SKINKER, THOS. J., 417, 420
SKINNER, THOS. J., 419
SMEDBERG, C. W., effect of impounding reservoir on water at Greensboro, N. C., 62 seq.
SMITH, N. R., 369 seq.
SPELLER, F. N., 605
STALEY, G. C., 711
STAPLETON, 718
STARR, R. H., 455 seq., 545
STEDMAN, A. W., 717
STEELSMITH, D. C., 421
STEPHENSON, F. H., 414
STEVENSON, W. L., 337
STOKES, D. B., 415
STOKES, W. R., 166, 168
STRAUB, JOS. W., 417
STREETER, H. W., 281
STROUSE, P. E., 717, 719
STROUT, GALE S., 156
SUGGS, J. H., 51
SUMNER, R. S., 718
SWEDENBORG, 656
SYMONS, M. M., 639

TALBOT, A. N., 716
THERIAULT, E. J., 22
THOMAS, A. H. R., 518
THOMPSON, 50
THOMPSON, JOHN R., 595, 597
THOMSEN, P., 369, 385
THUMA, ROSS A., problems of hard and soft water, 152 seq.

TIEDEMAN, WALTER V. D., orthotolidine and starch-iodide tests for free chlorine in chlorinated sewage tanks effluents, 391 seq.
TOYNE, JOHN W., 711
TRACE, V. E., 105
Seismic activity in Santa Barbara, 404 seq.
TROMMSDORF, 377
TRUE, ALBERT O., 43 seq.
TURRE, GEO., 718

VAN, prefix VAN neglected for indexing
VAUGHAN, T. WAYLAND, 158 seq.
VEST, W. E., 53
VOORHIS, WARREN R., the invisible balance sheet, 481 seq.

WADSWORTH, G. A., 364, 715
WALL, EDWARD E., 414
WARING, F. H., 138
WARWICK, C. L., 413
WATERMAN, EARLE L., 420
placarding public water supplies along tourist highways, 365 seq.
WEBSTER, KEITH, 521 seq.
WEIR, W. H., 49
WELCH, W. H., 415
WESTON, ROBT. SPURR, 249
WHIPPLE, GEO. C., 155, 490
WHITE, H. D., 364
WHITMAN, 599, 605
WHITNEY, 599
WHYSALL, GEO., 714
WIGGIN, THOS. H., 414
WILLIAMS, ARNOLD, 103
WILLIAMS, D. M., 41
WILLIAMS, SHERMAN, 719
WILSON, E. B., 415
WILSON, F. C., 385
WILSON, NORMAN M. R., 457 seq., 520
WINSLOW, C. E.-A., 165 seq., 646
WOLFE, EDWARD E., 276
WOLMAN, ABEL, 22, 80
WOOD, C. R., 414
WOOD, D. R., 166, 168
WOOD, R. D., 415
WOOD, WALTER, 415
WOOD, W. N., 364
WYANT, CARL, 404
WYNNE-ROBERTS, R. O., 540 seq.

YOUNCE, W. L., 711

ZUCROW, MAURICE J., 709

INDEX TO ABSTRACTS

I. Authors

Abbott, G. A., 195
Abel, E., 436
Abt, G., *see* Pottevin and Abt
Adam, Noël, 584
Adams, B. A., 200, 727
Adeney, W. E., Leonard, A. G. G., and Richardson, A., 436
Aeryns, Albert N., *see* Wegmann, E., and Aeryns, A. N.
Agnew, J. R., 442
Ahlers, John G., 447
Allen, Charles, M., and Taylor, E. A., 321, 574
Allen, Henry A., 97
Amar, Charles, 586
American Journal of Public Health, 305
American Society of Civil Engineers, 735
Anderson, R. J., and Enos, G. M., 441
Angus, Robt. W., 311, 730
Armstrong, Jas. W., 182, 192, 560
Armstrong, Kenneth C., 580
van Arnum, W. I., 301
Arroyo, Salvador, 189
Asher, Richard, 449
Atkey, A. R., 211
Atkin, W. R., and Gardner, A., 430
Atkins, W. R. G., 196, 197, 317, 318, 435
Aubin, P. A., *see* Rushton, W., and Aubin, P. A.; Rushton, W., Aubin, P. A., and Jenkins, A. J.

Baer, 429
Bahlman, Clarence, 303, 304
Bahr, H., and Kather, K., 577
Bailey, Frank S., 578
Bailey, T. Lewis, 573, 735
Baird, Samuel P., 445
Baker, C. M., 426
Baker, J. C., 734
Banerji, Nani Lal, 307
Barbour, F. A., 561
Bardwell, R. C., 208, 327, 577
Barnett, M. Ratcliffe, 315
Barousch, Johann, 94
Barr, W. M., 208
Bastin, E. S., Greer, F. E., and Moulton, G., 445
Bates, P. H., 179
Bauer, John, 212
Baughman, H. H., 97
Baylis, John R., 207, 310
Beale, J. F., *see* Thresh, J. C., and Beale, J. F.
Behrman, A. S., 209
Behrman, A. S., and de Celle, O. A., 209
de Belaevsky, Vladimir, 195
Bell, Wm. H., 440
Bengough, G. D., and Stuart, J. M., 576
Bennett, S. Barlow, 586
Bernard, J. A., 313
Berolzeimer, D. D., *see* West, C. J., and Berolzeimer, D. D.
van Bers, G. H. C., *see* Vürtheim, A., and van Bers, G. H. C.
Bigelow, W. D., and Stevenson, A. E., 572
Bingham, E. C., Rolland, G. F., and Hilbert, G. E., 207
Bintz, Wesley, 427
Black, E. B., 184
Blackburn, Alfred B. E., 211
Blair, E. M., *see* Wilson, W. J., and Blair, E. M.
Blake, H. P., *see* Grime, E. M., and Blake, H. P.
Block, B., 84
Blough, E., 186
Blythe, Allen T., 183
Bonnet, R., *see* Hee, A., and Bonnet, R.
Boldry, Chas., 423
Bondo, Erik, 435
Bonna, A., 426
Bowman, John, 86
Boyce, Ernest, 442
Boyd, J. E., *see* Slack, S. B., and Boyd, J. E.
Bradbury, Richard R., 443
Brewer, A. F., 728

Briggs, B. A., 729
Briggs, G. H., 567
Brooks, John N., 447
Brown, Arthur, 209
Brown, John S., 319
Brownstead, J. P., 300
van Brunt, Chas., 207
Bryan, L. L., *see* Stearns, H. T., and Bryan, L. L.
Buchanan, E. V., 321
Buckley, M. J., 89
Bull. Trimestriel Assoc. Internat. de Bains Populaires et de Propreté, 93
Bunau-Varilla, Philippe, 205
Burgess, Edwin, *see* Nichols, L., and Burgess, E.
Burgess, W. T., 734
Burnet, F. M., 430
Butcher, I. A., 729
Butler, Wm., and Coste, J. H., 434
Buxton, E. P., *see* Jones, G. W., Yant, W. P., and Buxton, E. P.

Calendoli, E., *see* Rossi, G., et al.
California Department of Public Works, 320
Calmettes, Pierre, *see* Negrier, P., et al.
Canada Topographical Survey, 321
Canadian Engineer, 321
Carey, W. Gordon, 211
Carré, 439
Carrick, O. W., 208
Caskie, John A., 423
Caspari, Fred W., 331
Castagne, Robt., 196
Castelli, Gaetano, 431
de Celle, O. A., *see* Behrman, A. S., and de Celle, O. A.
Chace, C. R., 730
Chapin, Chas. V., 333
Chapman, W. B., 433
Chase, E. Sherman, 178, 323
Chatley, Herbert, 313–4
Cheyne, G. C., *see* Leete, F. A., and Cheyne, G. C.
Chemiker Zeitung, 439
Chicago Department of Health, 316
Chorley, R. W., 208
Christensen, L. M., and Fulmer, E. I., 207
Clark, Ernest A., 311
Clark, Frank Wigglesworth, 332
Clark, H. W., 97, 178, 560
Clarke, Wm. O., 85
Classon, W. G., and Sherman, C. W., 562
Cleverdon, Walter S. L., 211
Cobbett, L., 563
Coff, Chas. R., 330
Colborn, C. E., 729
Colizza, C., *see* Rossi, Giacomo, et al.
Collet, L. W., 314
Collinson, Geo. R., 89
Cone, W. A., 186
Connecticut State Department of Health, 101
Conner, C. N., 582, 583
Connolly, Joel I., 328
Contract Record, 193, 194, 210, 445, 581, 725, 726
Coote, P. C., 563
Copeland, Wm. R., 189
Copisarow, Maurice, 435, 436
Cornewell-Walker, A. E., 211, 734
Coste, J. H., *see* Butler, Wm., and Coste, J. H.
Coughlan, R. E., 208
Coulaud, E., 95
Coulter, Waldo S., 97, 442
Cremier, R., *see* Vigne, P., and Cremier, R.
Crewdson, Eric, 574
Crews, W. P., 438
Crum, W. L., and Patton, A. C., 333
Cummings, G. A., 312
Cunningham, F. G., 180
Cunningham, J., 732
Cunningham, J. M., 567

Dalal, C. C., 192
Dallyn, F. A., 322
Davidson, J. H., 326
Davidson, J. R., 726, 733, 734
Dawes-Dekker, Mme. A. M. Ruysch, 93
de, Prefix de neglected for indexing purposes
Dehler, Sophie A., *see* Havens, L. C., and Dehler, S. A.
Delery, Eugene F., 559
Denigès, G., 438
Deplantade, E., 313
Dienert, F., 197, 198
Dillon, Chas., 327
Dintr, V., 316
Dittoe, W. H., 300
Dixon, Fred J., 564
Dodson, Wm. C., 433
Dolson, F. O., and Huber, W. L., 98
Donaldson, Wellington, 182, 194, 442
Dougherty, N. W., 180
Downs, A. S., 93
Drake, H. P., *see* Waterman, E. L., and Drake, H. P.
Dubief, J., *see* Touplain, F., and Dubief, J.

DUFFIE, C. A. P., 578
DUGAN, F. C., 579
DUMBLETON, J. E., 449
DUNHAM, H. F., 721
DURAND, R., 434, 566
VAN DUSEN, C. T., 569

EAST, W. E., 425
EATON, E. COURT, 444
L' EAU, 94, 95, 210
EDDY, H. P., 183
EDWARDS, E. T., 300
EFFRONT, JEAN, 196
EGLEHOFF, R. F., 720
ELDRIDGE, E. F., *see* HIRN, W. C., and ELDRIDGE, E. F.
ELLIS, A. J., and MEINZER, O. E., 320
ELLMS, J. W., 182
ELLIS, DAVID, 423, 732
Engineering and Contracting, 97, 311, 559,
Engineering News-Record, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 443, 444, 445, 446, 447, 577, 578, 579, 580, 581, 582, 720, 721, 722, 723, 724, 725, 726, 735, 736
ENOS, GEO. M., 206, 439, *see* ANDERSON, R. J., and ENOS, G. M.; SILVID, W. A., and ENOS, G. M.
ENSLOW, LINN H., 310
ERDMAN, L. N., 437
ERICKSEN, SILVERT, 428
Erie, Pa., City of, 99
EUSTICE, J., 562
EVANS, S. HAROLD, 190
EVANS, ULICK R., 439
EYDOUX, D., *see* RATEAU, A., et al.

FABRIAN, F. W., 316
FARR, ARTHUR V., 316
VON FELLENBERG, TH., 440
FETZER, W. R., 205
FIELD, F. E., 560
FIELD, JOHN E., 722
FINCH, L. S., 323
Fire and Water Engineering, 312
FLOCKART, A. P., 720
FISHER, E. A., 437
FLOOD, GERALD M., 424
FLU, P. C., 439
FORD, JOHN L., 442
DE LA FOREST, M. LE COUPPEY, 584
FORMAN, LEROY, 195, 198
FORTIER, S., and SCOBEY, F. C., 98
FOULK, C. W., 736–7
FOURNIER, RAYMOND, 439
FOWKE, GERRARD, 195
FOX, J. R., 87
FRAENKEL, W., 318
FRANCIS, A. G., 317
FRENCH, CHAS. A., 183
FRIEND, J. A., NEWTON, 99, 575
FRIEND, ROBT. O., 92
FRONCZAK, FRANCIS E., 93
FROST, W. H., 309
FUJIHARA, T., 205
FULLER, HARRY U., *see* METCALF, L., FULLER, H. E., and MITCHELL, C. B.
FULMER, ELLIS I., *see* CHRISTENSEN, L. M., and FULMER, E. I.
FURNESS, REX, 317

GARDNER, A., *see* ATKIN, W. R., and GARDNER, A.
GARDNER, D. A., 567
GARILL, M., *see* RATEAU, A., et al.
GARLAND, C. M., 330, 568
Gas Age-Record, 197
DE GEER, B. W., 208
GEGENHEIMER, R. E., 434
le Genie Civil, 426, 429
GEORGIADES, 317
GERSBACH, ALFONS, 199
GICHNER, JOSEPH E., 93
GILBERT, J., 428
GILA, F. A., *see* GIRAL, J., and GILA, F. A.
GILZEN, K. K., 431
GIRAL, J., and GILA, F. A., 439
GISH, A. H., 429
GLASS, E. EARL, 579
GLASSPOOLE, JOHN, 91
GLASSPOLE, W., 733
GLUUD, W., and SCHÖNFELDER, R., 573
GOODRICH, A. E., *see* WOLMAN, A., GOODRICH, A. E., and SPRING, W. N.
GORDON, FRED G., *see* MAURY and GORDON
GORDON, J. G., 186
GORE, WM., 183
GORMAN, ARTHUR E., 425
GREER, FRANK E., *see* BASTIN, E. S., et al.
GRIME, E. M., and BLAKE, H. P., 326
GROETSCHUL, 198
GROSSFELD, J., 432
GRUVEL, A., 196
VAN GUNDY, C. P., 208
GWINN, A. P., 331

HACHEZ, 427
HALL, F. G., 432
HALL, GEO. L., 331
HALL, RALPH, E., 567, 728

HALTON-THOMPSON, D., 733
HANCOCK, H. S., JR., 193
VON HANFSTENGEL, G., 441
HANLEY, J. P., 208
HANSEN, A. A., 429
HANSEN, PAUL, 178, 325
HARRIS, NORMAN MACLEOD, 194, 424
HATTON, JOHN, 93
HAVENS, L. C., and DEHLER, S. A., 437
HEE, A., and BONNET, R., 195
HIGGINS, E. B., and O'CALLAGHAN, J. P., 100–1
HIGGINS, GEO., 585
HILBERT, G. E., *see* BINGHAM, E. C., ROLLAND, G. F., and HILBERT, G. E.
HILDEBRAND, R., 568, 730, 731
HILDITCH, T. P., and WHEATON, H. J., 101, 307
HILGER, W. E., *see* SELTER, H., and HILGER, W. E.
HILL, NICHOLAS S., JR., 102
HINDS, JULIAN, 98–9, 181
HINMAN, JACK J., JR., 205
HIRN, W. C., and ELDRIDGE, E. F., 101, 194, 585
HOBBS, W. H., 208
HODGKINSON, F., 730
HODGMAN, B. B., 560
HOGAN, M. A., 212
HOLDCROFT, J. B., 321
HOLWAY, W. R., 185
HOOD, WALTER S., 93
HOOVER, CHAS. P., 208, 301, 427
HOPKINS, EDWARD S., 206
HORROCKS, Sir WM., 428
HOSKINS, J. K., 309
HOTCHKISS, MARGARET, *see* WINSLOW, C.-E. A., and HOTCHKISS, M.
HOUK, IVAN E., 310
HOUSLEY, J. E., 567
HOUSTON, Sir ALEXANDER C., 199–205, 733, 734
HOWARD, N. J., 581
HUBER, WALTER L., *see* DOLSON, F. O., and HUBER, W. L.
HUBBARD, C. L., 569
HULL, THOS. G., 195
HUMPHREY, JOHN F., 93
HUNT, HORACE S., 84
HURST, H. E., and WATT, D. A. F., 90
HUSS, HARALD, 333
HUTCHINSON, G. W., 179, 583
HUY, HARRY F., 311

IGONET et DE LAROCHE, 95
IMBEAUX, ED., 314
Indiana State Bd. of Health, 101

JAGIC, N., and SPENGLER, G., 317
JAMESON, ALEX. H., 423
JENKINS, A. J., *see* RUSHTON, W., AUBIN, P. A., and JENKINS, A. J.
JENKS, HARRY N., 188
JEPSON, C. P., 570
JERDEN, ALFRED, 570
JEROME, HARRY, 333
JOANNIDES, GEO. SP., 425
JOHNSON, E. M., 428
JOHNSTON, JOHN, 318
JOHNSTONE-TAYLOR, F., 184, 565
JONES, B. E., 722
JONES, G. W., YANT, W. P., and BUXTON, E. P., 320, 577
JORGENSEN, LARS, 446
Journal Royal Sanitary Institute, 312
JUSTIN, JOEL, D., 84
JUSTIN-MUELLER, ED., 432

KAISER, CLARENCE T., 185, 302
KATES, EDGAR J., 330
KATHER, K., *see* BAHR, H., and KATHER, K.
KEILEY, J. D., 325
KELSEY, JOHN W., 182, 442, 582
KERNEN, G., 94
KHALIL, H., 426
KILLEFER, D. H., 316
KIRKHAM, V. R. D., *see* LANEY, F. B., KIRKHAM, V. R. D., and PIPER, A. M.
KLAPP, CARL F., 580
DE KLEINE, WM., 96
KNOPP, L. F., 184
KNOWLES, C. R., 325
KNOWLES, M., MANSFIELD, M., and NUGENT, P., 561
KOHMAN, EDWARD F., 572
KOLTHOFF, I. M., 434
KOPACZEWSKI, W., 449, 586
KOSER, STEWART A., 203
KOYL, C. HERSCHEL, 208
KRAEMER, HENRY, 576
KRÄNZLIN, GOTTFRIED, 431
KUNIGK, W. A., 579

L', Prefix L' neglected for indexing
LABACH, P. M., 208, 326
LABOON, J. L. F., 324
LAIDLAW, P. P., 430
LAKEMAN, ALBERT, 331
LAMPE, B., 572
Lancet, 424
LANE, E. W., 724, 736
LANEY, F. B., KIRKHAM, V. R. D., and PIPER, A. M., 85
LANNING, J., 194

DE LAROCHE, *see* IGONET et DE LAROCHE
LA RUE, E. C., 448
LATHAM, ERNEST, 90
LAURENT, FERNAND, 584
LAWSON, L. M., 189, 724
LE, Prefix LE frequently neglected for indexing purposes
LEBRUN, 434
LEDOUX, MAURICE, 449
LEETE, F. A., and CHEYNE, G. C., 211
LEHR, GEO., 449
LEITCH, R.D., 329
LEONARD, A. G. G., *see* ADENEY, W. E., LEONARD, A. G. G., and RICHARDSON, A.
LEPAPE, ADOLPHE, 440
LEVIE, A., 428
LHEUREUX, PAUL, 94
LEVINE, VICTOR E., 207
LIEFRINCK, F. A., 315
LINDSAY, E. C., 301
LIPPINCOTT, J. B., 721
LITTLEFORD, R. D., 178
LONGLEY, F. F., 561
LORMAND, CH., 195

MACALISTER, JAS., 90
MACAULAY, FRED W., 88, 211
MACHEMER, H. W., 326
MAGER, F. W., 563
MALTBY, A. T., 445
MANSFIELD, M., *see* KNOWLES, M., et al.
MANSON-BAHR, PHILIP, 211
MARCANO, OCTAVIO, 312
MARCELLUS, J. B., 184, 312
MARECHALAR, M. *see* NEGRIER, PAUL, et al.
MARQUET, GASTON, 94
MAROTTA, D., 433
MARSH, H. M., and MCLELLAND, W. J., 581
Maryland State Department of Health, 315, 330
MATTSON, T. E., *see* MILLARD, E. B., and MATTSON, T. E.
MAUGÉ, LUCIEN, 100
MAURY, DABNEY, *see* MAURY and GORDON
MAURY and GORDON, 442
MAXWELL, W. H., 563
MAYNZ, THEODORE, 308
MCCAVOUR, S. T., 725
MCDONNELL, ROBT. E., 311
MCGUIRE, C. D., 427
MCKAY, ROBT. J., 576
MCCLEAN, W. N., 733
MCLELLAND, W. J., 581, *see* MARSH, H. M., and MCLELLAND, W. J.
MEINZER, OSCAR E., *see* ELLIS, A. J., and MEINZER, O. E.
MELLEN, ARTHUR E., 179
MESSER, RICHARD, 184
MESSERLI, F. M., 95, 426
METCALF, L., FULLER, H. U., and MITCHELL, C. B., 561
MEYER, ADOLPH F., 84
MICHAELIS, L., 436, 449
Michigan Department of Health, 101, 323, 428
MILES, W. M., 586
MILLARD, E. B., and MATTSON, T. E., 96, 313
MILLER, L. B., 327, 329
MINGLE, J. G., 567, 569, 728
MISTRANGELO, CLAUDIO, 332
MITCHELL, C. B., *see* METCALF, L., FULLER, H. U., and MITCHELL, C. B.
MITCHELL, GEO., 90, 314, 572
MITCHELL, LEWIS, 571, 572
MOLE, HARRY H., 97
MOLLIEX, P., 332
MORRISON, ROGER L., 210
MOULTON, GAIL, *see* BASTIN, E. S., et al.
MOYER, S. L., 183
MUESER, WM., 180
MÜLLER, W., 441
Municipal Engineering, 193
MURAOUR, HENRI, 437
MURPHY, D. W., 721

NASH, L. R., 586
NEGRIER, P., CALMETTES, P., and MARECHALAR, M., 449
NELSON, B. STANLEY, 736
NEUBERG, 435
New Jersey Department of Conservation and Development, 320
New Jersey State Department of Health, 194, 322
New York State Department of Health, 322, 323, 429, 430
NEWELL, A. B., 569
NICHOLS, L., and BURGESS, E., 430
NILES, PHILIP B., 311
NOETZLI, FRED A., 184
NORMAN, H. A., 187
North American Veterinarian, 428
NUGENT, P., *see* KNOWLES, M. et al.
NYDEGGER, OTTO, 437

OBERLE, WM. E., 187
O'CALLAGHAN, J. P., 308, *see* HIGGINS, E. B., and O'CALLAGHAN, J. P.
O'CONNOR, P. J., 301
O'GRADY, S. C., 90
Ohio Conference, 300–4

Ohio State Board of Health, 322
Olszewski, W., 435
O'Shaughnessy, M. M., 186, 722
Oswald-Klinck, 100

Palmieri-Nuti, E., *see* Rossi, G., et al.
Paris, G., 432
Parker, 86
Parshall, Ralph L., 98
Patterson, A. McC., 564
Patterson, W., 734
Patton, Alson Currie, *see* Crum, W. L., and Patton, A. C.
Paul, C. H., 212
Pawan, J. L., 312
Peabody, Geo. F., 93
Pederson, H. V., 311
Pennsylvania Department of Forests and Waters, 449
Perrin, Jean, 205
Pfeiffer, O., 198
Phelps, Earle B., 211
Pickels, Geo. W., 586
Piper, A. M., *see* Laney, F. B., Kirkham, V. R. D., and Piper, A. M.
Plants, J. W., 97
Poebing, O., 332
Pottevin and Abt, 424
Powell, S. T., *see* Schaetzle, T. C., and Powell, S. T.
Powell, S. T., and Wolfe, J. H., 96
Power, 330, 567, 729, 730, 731
Power Plant Engineering, 323, 324
Pratt, Arthur H., 191
Preston, F. M., 209
Prichard, Henry S., 310
Prior, John C., 722
Public Health Reports, 328, 329
Public Works, 310, 311, 559, 584, 585

Race, Jos., 733, 734
Railway Engineering and Maintenance, 325, 326
Railway Review, 327
Raju, V. Gobinda, 313, 425, *see* Stewart A. D., and Raju, V. G.
Rakuzin, M. A., 437
Ranson, Wm., 559
Rashkovitch, S., 571
Rateau, A., Eydoux, D., and Garill, M., 586
Raymond, Wm. G., 211
Rechnagel, H., 333
Redfern, A. J., 210
Rees, O. T., 208
Reinhard, Geo. C., 330
Renick, B. Coleman, 319, 320
Rewald, 435
Ricart, D. F., 423
Richardson, A., *see* Adeney, W. E., Leonard, A. G. G., and Richardson, A.
Richardson, B., 438
Richardson, H. H., 208
Riegel, Robt., 333
Riesenfeld, E. H., 434
Riffenberg, H. B., 321
Riker, I. K., and Sparmaker, C. W., 571
Risley, W. J., Jr., 735
Ritchie, E. G., 446
Ritter, Walter, 438
Robbins, Henry C., *see* Taylor, F., et al.
Roberts, Cecil H., 734
Rohrer, J. K., 189
Rolants, E., 95
Rolland, G. F., *see* Bingham, E. C., Rolland, G. F., and Hilbert, G. E.
Ross, A. W., 559
Rossi, G., Calendoli, E., Colizza, C., and Palmieri-Nuti, E., 441
Rothery, S. L., 725
Roux, 426
Rose, 436
Rudeloff, 431
Rupp, Daniel H., 301, 303
Rushton, W., and Aubin, P. A., 732
Rushton, W., Aubin, P. A., and Jenkins, A. J., 91

Salmon, Alfred, 94
Sanford, E., 331
Saville, Caleb Mills, 191, 323, 443
Schaetzle, T. C., 330, 331
Schaetzle, T. C., and Powell, S. T. 331
Scheer, K., 438
Schiedt and Stockmann, 572
Schilling, F. H., 440
Schleicher, A., 438
Schlotthauer, F., 332
Schönfelder, R., *see* Glund, W., and Schönfelder, R.
Schramm, G. N., *see* Vinal, G. W., and Schramm, G. N.
Schrieber, Paul, 440
Schweizer Bauzeitung, 584
Scobey, Fred C., 190, *see* Fortier, S., and Scobey, F. C.
Scott, L. C., 322
Selter, H., and Hilger, W. E., 440
Selvig, W. A., and Enos, G. M., 434
Shanly, C. N., 84
Shaw, Arthur L., 181, 191

SHEPPARD, G. M., 559
SHERMAN, CHAS. W., 183, *see* CLASSON, W. G., and SHERMAN, C. W.
SHERMAN, W. J., 442
SHERRERD, MORRIS R., 312
SHOUDY, W. A., 729
SLACK, S. B., and BOYD, J. E., 180
SMIT, JAN, 438, 571
SMITH, 2ND, E. E., 301
SMITH, LEON A., 426
SMITH, W. C., 437
SMITH, WALDO E., 585
SMULSKI, EDWARD, *see* TAYLOR, F., et al.
SOHN, HENRY, 304
SPARMAKER, C. W., *see* RIKER, I. K., and SPARMAKER, C. W.
SPENGLER, G., *see* JAGIC, N., and SPENGLER, G.
SPERRY, WALTER A., 194
SPRING, W. N., *see* WOLMAN, A., GOODRICH, A. E., and SPRING, W. N.
SPURR, HENRY C., 333
STABLER, HERMAN, 724
STANTON, H. B., 567
STEARN, ALLEN E., *see* STEARN, E. W., and STEARN, A. E.
STEARN, E. W., and STEARN, A. E., 206
STEARNS, H. T., and BRYAN, L. L., 319
STEEL, DAVID A., 208
STEIK, K., 318
STEVENS, J. C., 191
STEVENSON, A. E., *see* BIGELOW, W. D., and STEVENSON, A. E.
STEVENSON, W. L., 101–2
STEWART, A. D., and RAJU, V. G., 313
STEWART, SPENCER W., 189
STOCKMANN, *see* SCHIEDT and STOCKMANN
STREETER, H. W., 97, 309
STROMSTEN, FRANK A., 99
STUART, J. M., *see* BENGOUGH, G. D., and STUART, J. M.
STULL, R. C., 316
STUMPER, ROBT., 318
Surveyor, 571
SUTHERLAND, J. R., 87
SWEENEY, R. C., 300
SYPES, G. G., 190

TAYLOR, E. A., *see* ALLEN, C. M., and TAYLOR, E. A.
TAYLOR, FREDERICK, et al., 331
TAYLOR, STEPHEN H., 562
TAYLOR, W. T., 212
TECHOUYÈRE, EMILE, 205
TENNEY, E. H., 729
TERR, WM., 211
THERIAULT, EMERY J., 309
THIEM, G., 332
THOMAS, ROBT. J., 580
THOMAS, STANLEY, 449
THOMPSON, W., *see* TAYLOR, F., et al.
THRESH, JOHN C., 200
THRESH, J. C., and BEALE, J. F., 727, 733
TIFFANY, R. K., 189
TOBEY, JAS. A., 333
TOCH, M., 574
TOUPLAIN, F., and DUBIEF, J., 433
TREMBLAY, J. A., 560
TRINKS, W., 433
TROWBRIDGE, C. E., 303
TULLIS, R., 730
TURNER, C. A. P., 445
TYLER, R. G., 560
TYSON, T. H., 89

VAIL, 731
VAN, Prefix VAN neglected for indexing purposes
VANCE, LOREN R., 96, 313
VERNON, W. H. J., 574
VERSLUYS, J., 314, 316
VICKERY, F. P., 424
VIGNAL, 429
VIGNE, P., and CREMIER, R., 95
VIGNERON, H., 584
VINAL, G. W., and SCHRAMM, G. N., 730
VIOLLE, H., 95
VÜRTHEIM, A., and VAN BERS, G. H. C., 432

WAESER, B., 441
WAGNER-JAUREGG, J., 317
WALKER, C. L., et al., 574
WALSH, W. F., 567
WANDENBULCKE, L., 196
Water and Water Engineering, 306, 308, 314, 423, 424, 563, 564, 565, 566, 726
WATERMANN, E. L., and DRAKE, H. P., 85
WATSON, T. P., 583
WATT, D. A. F., *see* HURST, H. E., and WATT, D. A. F.
WEGMANN, E., and AERYNS, A. N., 184
WEIGHTMAN, H. E., 566
WELCH, WM. HENRY, 211
WELLS, JAS. P., 188
WELSCH, W. F., 446
WEST, C. J., and BEROLZEIMER, D. D., 212

WESTON, ROBT. SPURR, 323
WHEATON, H. J., *see* HILDITCH, T. P., and WHEATON, H. J.
WHEELER, WALTER H., 179
WHERRY, WM. M., JR., 332
WHITTAKER, H. A., 582
WILLIAMS, G. M., 583
WILLIAMS, GARDNER S., 183
WILLIAMSON, F. S., 432
WILLIAMSON, LEE H., 184
WILSON, F. C., 573
WILSON, W. J., and BLAIR, E. M., 430
VAN WINKLE, FRANKLIN, 569–70, 731–2
WINSLOW, C.-E. A., and HOTCHKISS, M., 441
WINSTANLEY, A., 305
WOLFE, J. H., *see* POWELL, S. T., and WOLFE, J. H.
WOLFE, THOS., 188
WOLMAN, ABEL, 315, 330, 331
WOLMAN, A., GOODRICH, A. E., and SPRING, W. N., 331
WOOD, JOS. K., 317
WOOD, W. P., 436
WOODMANSEY, A., 437
World Power Conference, 212
WYNN, A. E., 448

YANT, W. P., *see* JONES, G. W., YANT, W. P., and BUXTON, E. P.

ZSCHOKKE, B., 573

INDEX TO ABSTRACTS

II. Subjects

Aberdeen, Scotland; water supply, new, and, 314, 572
Acid; resistance and; materials and, 317, 439, 441
Acid Water; corrosion and, 434
metallography and, 441
monel metal and, 576
resistance and, 439
East Liverpool, Ohio, and, 301
softening and, 314
South Pittsburgh, Pa., and, 303
see Corrosion
Aëration; adoption, increasing, and, 442
atmosphere and; quiescence and, 436
sodium chloride and, 436
streams and, 309
temperature and, 436
Aftergrowth; excess lime and, 727
reservoirs and, 727
Agar; absorption and, 196
chemical constitution and, 196
Agfil; *see* Boiler Scale
Aggressive Water; *see* Corrosive Water
Air; solution and; bubble formation and, 208
supersaturation and, 208
see Air-Binding
Air-Binding; causes and, 208
prevention and, 208
Air-Valve; penstock; type, new, and, 193
Algae; control and; Jersey, C. I., and, 732
fish life and, 733
oxygen dissolved and; respiration and, 195
tropical conditions and, 313
Algiers; water supply and; Roman remains and, 94
Alkali; waters; treatment and, 312
Alum; basic sulfate precipitate and, 432
floc and; anions and, 327
Aluminium; *see* Calorizing
American Society for Testing Materials; specifications and, 722
Amsterdam, Holland; water supply and, 315
Analysis; interpretation and, 737
methods and, 737
objects and, 736
pollution and, 582
reporting and, 736
see Boiler Water; Books, New
Analysis; Alkalinity and; alizarin and, 431
bromophenol blue and, 431
buffer standard and, 431
methyl orange and, 430
Barium and; determination and, 317
Calcium and; determination, volumetric, and, 432
Carbon Dioxide and; gas-volumetric method and, 432
Carbonate and; sulfide removal and, 433
Chloride and; sea water and, 439
Chlorine Absorption and; indigo-carmine and, 566
Chlorine, Available, and; gas-volumetry and, 434
potassium iodide and, 434
Gases Dissolved and; hydro-carbons and, 320, 577
Hardness and; soap test, modified, and, 432
see Analysis; Alkalinity and
Hydrogen-Ion Concentration and; media and, 436
Hypochlorite and; arsenious acid and, 438
potassium iodide and, 434
see Analysis; Chlorine, Available, and
Iodine and; methods, special, and, 440
sulfide and, 432
Iron and; standards, permanent, and, 206
Magnesium and; colorimetric method and, 438

Manganese and; benzidine and, 435
Nitrate and; Grandval-Lajoux method, modified, and, 573
Phenol and; determination and, 96, 313
interfering substances and, 302
p-nitroaniline and, 440
Strontium and; determination and, 317–8
Sulfate and; acidimetric method and, 196
benzidine method and, 435
Thiosulphate and; solutions and; aging and, 436
Annapolis, Md.; water supply and, 180
Antietam Creek; study, analytical, and, 331
Arabia; well waters and, 317
Army; Britain and; field supplies and, 428
Asterionella; Jersey, C. I., and; taste absence and, 732–3
Atmosphere; carbon dioxide equilibrium and, 435
oxygen equilibrium and, 435
Aurora, Ill.; water supply and, 184

Bacteriological Examination; B. Coli test and; Gambusia and, 437
supremacy and, 204
citrate test and, 203, 312
Coli group differentiation and, 203, 312
media and; hydrogen-ion concentration and, 436
presumptives, non-confirming, and, 304
rapid three star system and, 203
standardization and; France and, 95
sulfite reduction and, 430
see Books, New; Endo
Bacteriophage; water purification and; significance and, 439
Bacterium; deep earth strata and, 445
differentiation and, 206
dyes and; growth restriction and, 430
massive inoculation and, 430
growth and; chlorides and, 441
hydrogen peroxide formation and, 430
hydrogen sulfide formation and, 431
reduction and; selenium indicator and, 207
sulfite test, and 430
simulation and; structures, inorganic, and, 430
see Books, New
Bacterium Aërogenes; pollution, non-fecal, and, 97
Bacterium Cloacae; pollution and; attenuation and, 97–8
Bacterium Coli; fecal and non-fecal types and, 312
Gambusia and, 437
hydrogen-ion concentration and; limits and, 438
Pyocyaneus and, 437
soil and, 441
tropics and, 312
Bacterium Coli Group; differentiation and, 97–8, 203, 205, 312
warm-blood and cold-blood types and, 435
Bacterium Typhosum; hydrogen-ion concentration and, 438
morphology and, 430
reduction and, 430
Ball, Cleaning; dislodgment, difficult, and, 183
Baltimore, Md.; L. Raven reservoir and, 192
Barium; action, physiological, and, 437
brines, natural, and, 317
Harrogate, Eng., waters and, 437
Base Exchange; zeolites, natural, and, 318, 319; *see* Zeolite
Bath, England; history and, 93
Bath, Public; see Books, New
Bathing Beach; protection and; New Jersey and, 194
typhoid and, 582
Baton Rouge, La.; water supply and, 724
Bearing Metal; "thermit"; new, improved, 441
Beckton, England; filtration, mechanical, and, 308
Belgium; water supply and; national association and, 427
Berm; flow and; impediment and, 190
Besançon, France; water supply and; antiquity and, 94
Bleaching Powder; manufacture and, 437; *see* Hypochlorite
Boiler; efficiency and; Brown & Sharpe Manufacturing Co. and, 729
carbon dioxide control and, 438
superheat and, 438
gas-fired; explosion danger and, 730
oil-fired; instructions and, 728
water-tube and, 567, 728

operation, rational, and, 308
sodium carbonate hydrolysis and, 572
see Furnace
Boiler Compound; sphere of, 737
Boiler Corrosion; electrolyte concentration and, 305–6
electrolytic action and, 728
grooving and, 305
oxygen and, 728
pitting and, 305
prevention and, 327, 567
sodium chloride and, 728
sodium hydroxide and, 728
sodium sulfate and, 305, 728
tube failure and, 438
Boiler Feed Water; feed control devices and, 569
heaters and, 327
oil removal and, 304
treatment and, 211, 308, 324, 432
carbon dioxide and, 572
financial advantages and, 208, 581
oxygen and, 572
zeolite and, 96
Boiler Foaming; surface tension and, 96, 313
theory and, 737
Boiler Priming; *see* Boiler Foaming
Boiler Scale; constituents and, 728, 737
control, definite, and, 567
prevention and; Agfil process and, 567
sodium phosphate and, 567
structure and, 728, 737
sulfate : carbonate ratio and, 567
Boiler Tube; failure and; causes and, 330, 438
Boiler Water; concentration and; corrosion and, 305–6
flaxseed treatment and, 429
testing and, 567
treatment and, 737
see Boiler Compound; Boiler Corrosion; Boiler Scale
Bombay, India; pipeline construction and, 306
Tansa Lake supply and, 306
Books, New:
Analysis of Potable Waters, 332
Bacteriology, 449
Les Bains à travers les Âges, 449
Zur Bestimmung Strömender Flussigkeiten im offennen Gerinne, 332
A Bibliography of Bibliographies on Chemistry and Chemical Technology, 212
The Chemistry of Power Plant, 586
The Colloidal State and Industry, 449
The Composition of the River and Lake Waters of the U. S., 332
Concrete, Plain and Reinforced, 331
Construction Plant, Methods, and Costs, 212
The Construction of Wells and Boreholes for Water Supply, 449
Drainage and Flood-Control Engineering, 586
The Economics of Public Utilities, 586
The Effect of Ions in Colloidal Systems, 449
Effective Regulation of Public Utilities, 212
Elementary Guide to Reinforced Concrete, 331
Elements of Business Statistics, 333
Guiding Principles of Public Service Regulation, 333
Industrial Water Supplies of Ohio' 736–7
The Installer of Pumps, 449
Introduction à l'étude des colloïdes, 586
Introduction to the Methods of Economic Statistics, 333
Kalender für das Gas- und Wasserfach, 332
Kalender für Gesundheitstechniker, 333
Lubricants; their Nature, Examination, and Use, 449
En Ny Indikator å Vattenförorening, 333
Practical Water Engineering, 212
The Principles of Public Health Engineering, 211
Provvista e Distribuzione di Acqua Potabile, 332
Public Health Law; a Manual of Law for Sanitarians, 333
Public Health in Theory and Practice, 211
Public Utilities and the Law, 332
The Public and its Utilities, 211
Regulation of Rivers without Embankments, 211
Report of Water Supply Commission of Pennsylvania, 449
River Gauging; a Report on Methods, etc., in Great Britain, 212
Statistical Method, 333
Technical Plumbing and Sanitary Science, 586

Théorie générale et formulaire pratique du ciment armé, 586
Transactions of the First World Power Conference, 212
Turbines hydrauliques, 586
Ueber Wasserversorgungsanlagen, 332
The Water Supply of Buildings and Rural Communities, 211
Borehole; *see* Books, New
Boston, Mass.; metering and consumption and, 578
water supply, additional, and, 578
Bradford, England; peaty water and, 193, 571
water supply, additional, and, 193, 571
Bristol, England; Cheddar supply and, 564
Britain; ground water and; protection and, 211
water supply conservation and, 572
water supply, rural, and, 210
Brookline, Mass.; water supply and, 179
Bubble; air-binding and, 208
formation and, 207–8

Calcium Carbonate; colloidal form and, 436
heteromorphism and, 435
Calcium Sulfate; heteromorphism and, 436
Calcutta, India; silt, fine, and; filtration difficulties and, 307
California, water rights and; report, biennial, and, 320
Calorizing; iron protection and, 316
Calumet City; reservoir, concrete, and, 311
tunnel, concrete, and, 311
water supply and; Chicago and, 311
Cambridge, England; pollution simulating sewage and, 563
Canada; topographical survey and; laboratory and, 321
Canal; permissible velocity and, 98
Canning; chlorination and, 572
hardness and, 572
water and; requirements and, 572
Carbon Dioxide; corrosion and, 205, 727
Montepulciano springs and, 431
see Carbonation; Water, Carbonated
Carbon Dioxide Recorder; principles and, 731
Carbonation; coke, flue gas, and oil and, 303
control and, 303
excess lime and, 727, 733
Newark, Ohio, and, 303
South Pittsburgh, Pa., and, 303
Catskill Supply; approaching completion and, 579
description and, 579
Cattle; water supply and; oil and, 428, 429
pollution and, 428
Cement; alumina; American; characteristics and, 210
strength and, 180
water control and, 179
committee report and, 735
strength tests and; questionable reliability and, 180
see Concrete
Cement gun; tunnel lining and, 185
Cemetery; ground water and; hygiene and, 426
Charleston, S. C.; sewage treatment and, 578
water supply and, 578
Chaudesaigues, France; mineral water and, 195
Chemical; dry-feed machines and, 301, 443
"Guta" automatic control and, 313
Chesterfield, England; water supply, new, and, 423
Chicago; Dept. Pub. Wks. and; report and, 559
goiter and, 316
metering and; cost and, 97
ordinance and, 190
report and, 442
water supply and; control, sanitary, and, 425
pollution and, 425
suburban towns and, 191
Chicago and Rock Island R. R.; water softening and; sodium aluminate and, 326
Chimney; capacity and, 569
dimensions and, 728
draught and, 567
Chimney Rock; *see* New Jersey
Chlorination; apparatus and; automatic, small-scale, and, 95
Paradon type, large, and, 179
corrosion and, 436
disinfection and; potency and, 440
emergency supply and, 429
hydrocyanic acid and, 434, 566
hydrogen sulfide and, 434, 566
mechanism and; theory and, 734
methods and; discussion and, 423
oysters and, 95, 734
patent litigation and, 304
phenol and (*see* Taste), 178

sewage and, 734
shell-fish and, 95, 734
slow sand filtration and, 425–6
super- and de-chlorination and; Java and, 316
sodium sulfite and, 316
Toronto, Ont., and, 581
swimming pools and, 734
wastes and, 734
see London, Eng.; Prechlorination; Taste
Chlorine; flue gas purification and, 303
liquid; Germany and, 437
Chloros; swimming pools and, 312
Cholera; lime and, 438
propagation and; water and, 424
Cincinnati, Ohio; bacterial results and, 304
chlorination and, 304
Eastern Hills reservoir and, 311
gas-formers, spore-bearing, and, 304
water supply and, 303
Clarifier; Newark, Ohio, and; performance and, 303
Clay; manufactures and; water purification and, 581
wastes purification and, 439
Coagulation; agitation, immediate, and, 192
alum and; anions and, 327
hydrogen-ion concentration and, 307, 327
alum-iron mixtures and; control and, 581
savings and, 581
application, intermittent, and, 313
double; Toronto, Ohio, and, 303
iron salts and; studies and, 329
sodium aluminate and, 300–1
sulfite liquor and; difficulty and, 207
Coal; pulverized; advantages and, 305, 435, 582
Des Moines, Iowa, and, 581
experiences and, 729
progress and, 425
purchase and; economy and, 567
Cochrane, Ont.; water supply, new, and, 194
Coke Plant; *see* Waste, Industrial
Colloid; corrosion theories and, 317; *see* Books, New
Color; charge, negative, and, 329
iron and, 732
removal and, 193, 329, 571
Colorado River; delta and; channels and, 725
flood control and, 448, 724
irrigation and, 448, 724
power development and, 448, 724
Columbus, Ohio; mains, cast iron, and, 722
report, annual, and, 427
Combustion; control and; flue gas analysis and, 438, 440; *see* Boiler; Books, New; Flue Gas; Furnace
Concrete; aggregate and; testing and, 180
aggregate, fine, and; testing and, 179
belt conveyor and, 724
cement : water ratio and, 446, 447
cold weather and, 84, 445
cracks and; repairing and, 720
dam disintegration and (*see* Gem Lake), 186, 722
diatomaceous earth and, 582, 583
field tests and, 581
mast and spout plant and, 443
mixtures and; control and, 446, 720
mixtures, "over-sanded," and, 583
pits, impervious, and, 448
protection and, 574
quantities and; estimation and, 579
reinforcement and; corrosion and, 573–4
protection and, 573–4
salts and; disintegration and, 318
sand surface area and, 583
sliding forms and, 720
strength and; edges and, 583
structures and; imperviousness and, 561
submergence and, 561
water and; disintegration and, 318
workability and, 583
see Books, New; Cement
Condenser; alloys and; suitability and otherwise and, 731
corrosion and; sea water and, 731
Conference; *see* Books, New; Ohio; State Sanitary Engineers
Connecticut; potable water and; survey and, 101
Consumption per Capita; Britain and; peaks and trends and, 86
metering and; reductions, notable, and, 321
Contracts; standard; progress report and, 735
Coolgardie, W. A.; pipeline and; corrosion, severe, and, 561
Copper; corrosion and; acidity and, 727
carbon dioxide and, 727
chloride and, 441, 576
mechanism and, 576
oxygen and, 727

pitting and, 576
salinity and, 727
sulfate and, 441
see Pipe, Copper
Copper Sulfate; application and; spraying machine and, 92
tropics and; diminished effectiveness and, 313
Corrosion; colloids and, 317
discussion and, 737
"dry"; mechanism and, 439
Lowell, Mass., water and, 580
measurement and, 205
metals, non-ferrous, and, 318, 574
mine water, acid, and, 434
residual metal and; testing and, 186
resistance and; alloys and, 439
surface systems and; importance and, 318
see Boiler Corrosions; Condenser; Copper; Iron, Corrosion and; Lead
Corrosive Water; Lowell, Mass., and, 580
Crenothrix; Lowell, Mass., and, 580
Cross Connections; prohibition and; Indiana and, 101
typhoid and; Niagara Falls, N. Y., and, 329
Curvature; gas saturation equilibria and, 207

Dam; Alouette Lake, B. C., and; construction and, 725
arch, experimental; tests and; program and, 184, 191
arch, multiple; Tidone, Italy, barrage and, 721
Black Canyon; water level control and, 181
disintegration and (*see* Gem Lake), 186, 722
earth; drains and, 183, 186, 192
failure and, 183, 184
Elephant Butte, 189
failure and; Bouzey, France, and, 195
L. Coedty, Wales, and, 726
L. Eigiau, Wales, and, 726
Sheffield and, 186
Junction, 84
miter lock gate type and, 124
New Jersey and; legislation and, 320
Norman, Lake of the Woods, 725
Oradell, N. J., 102
rock fill; Dix River and, 182
Wanaque; construction and, 187, 190
see Gem Lake; Spillway
Dechlorination ; *see* Chlorination
Delaware, Lackawanna, and Western R. R.; water station, new, and 326
Denver, Colo.; sand trap and, 310
water supply, new, and, 311
Deoxygenation; *see* Pollution
Depreciation; reserve and; practice, sound, and, 187
Detroit, Mich.; sewage project and, 582
Devil's Lake, N. D.; zinc and, 195
Diarrhea; outbreaks and; typhoid precursors and, 323
Diesel Engine; combustion and, 568
oil and; impurities and, 568
specifications and, 568
sulfur and, 568, 569
operation and, 730, 731
see Oil, Fuel
Disinfection; hydrogen-ion concentration and, 435; *see* Chlorine; "Ferrochlore" Process; Lime, Ozone; Sodium Hypochlorite; Ultra-violet Radiation
Distilled Water; corrosion and; copper and, 576
sterilization and, 576
Distillery; *see* Waste, Industrial
District; organization and; Maryland and, 331
Dix River; rock-fill dam and, 182
Doucil; application and, 307-8
constitution and, 101
description and, 307–8, 731
impurities, objectionable, and, 731
regeneration, rapid, and, 731
softening capacity and, 731
Drainage; *see* Books, New
Dry-Feed; *see* Chemical
Dyeing, Textile; corrosion trouble and, 433
Dysentery; amebic; water and, 211
bacillary; carriers and, 211
gastro-enteritis epidemic and, 732

Earthquake; Santa Barbara, Cal., and, 185
East Bay Water Co., *see* Mokelumne
East Liverpool, Ohio; phenol and; tastes and, 302
purification and; results and, 301
typhoid and, 302
Edinburgh, Scotland; per capita consumption and, 86
Eijkmann; test and; results, misleading, and, 198
Ejector; air; operation and, 729
Electric Power; breakdown prevention and, 730
Electrolysis; prevention and, 97

Endo; formula, improved, and, 194, 424
Engineering; *see* Books, New
Erie, Pa.; report, annual, and, 99
Eugene, Ore.; water supply and, 190, 192
Evaporation; soil and, 437
Everett, Wash.; water supply and, 580
welded pipe and, 580
wood-stave pipe and; frost and, 736
Extension; *see* Water Supply Finance

Feed; *see* Chemical
"Ferrochlore" Process; experiences and, 584
Paris, France, and, 584
Filter, Non-Submerged; phenol removal and, 198
ripening and; time requirement and, 198
Filtration; public and, 194; *see* Air-binding
Filtration, Double; adoption, increasing, and, 581
Bradford, England and, 193
Kilmarnock, Scotland, and, 193
London, Eng., and, 193, 202
Magdeburg, Germany, and, 198
Stuttgart, Germany, and, 581
Filtration, Rapid Sand; underdrains and; cemented gravel and, 182, 183
metal systems and, 182
perforated pipe and, 443
slat-bottoms and, 182, 561
Filtration, Slow Sand; alumina films and, 723
rates, notable, and; Montreal and, 560
tropics and; prechlorination and, 425–6
waste prevention and; chlorination and, 425
Finance; *see* Water Supply Finance
Fire Protection; sea water and; San Francisco and, 578
standpipe and, 311
Fish; chemicals and; toxicity and, 315, 331
chenopodium oil and, 315, 331
coke plant waste and; toxicity and, 434
oxygen dissolved and, 315, 331
zinc and; toxicity and, 195
Fittings; *see* Pipe
Flanders; water supplies and; conduit and, 426
Flange; strength and; formulas and, 100
Flood; *see* Books, New
Flow; berms and; interference and, 190
channels and; computation aids and, 585
constant; device and, 207
measurement and; methods and, 564
pipe, large, and channels and, 183
pitometer and orifice methods and, 447
salt velocity method and, 321, 574
velocity head and; utilization and, 559
venturi flume and, 98
see Books, New; Pipe, Flow and
Flue Gas; carbonation and, 303
chlorine purification and, 303
combustion control and, 438, 440
see Carbon Dioxide Recorder
Forest; run-off and, 314, 726, 734
see Watershed
Fort William, Ont.; water supply and, 193
French Landing, Mich.; dam and; failure and, 183
Furnace; air preheating and; economy and, 433
construction and, 566
fuel, low grade, and, 568
types, various, and; economy and, 433
see Boiler

Gage; loss-of-head, etc., and; principle, new, and, 188
Gambusia Affinis B. Coli index and, 437
B. Pyocyaneus and, 437
Gases Dissolved and; hydro-carbons and, 320, 577
Gem Lake, Cal.; dam and; disintegration and, 98, 179, 183, 186, 189, 446
Geneva, Switzerland; intake, new, and, 94
Glasgow, Scotland; water supply and, 87
Glass; hydrogen-ion concentration and; interference and, 316
Glauconite; zeolite, artificial, and, 101
Goiter; iodine prophylaxis and, 95, 316, 317, 322, 440, 560
iodine therapy and, 317
Saginaw, Mich., and, 96
water and, 95, 179, 322, 424, 440, 560
Goldfish; *see* Fish
Greenock, Scotland; water supply and; power development and, 90

Greensboro', N. C.; water supply and, 181
Grooving; *see* Boiler Corrosion
Ground Water; Britain and; protection and, 211
coastal; salt contamination and, 319
control, sanitary, and, 446
gases dissolved and, 320
methane and; significance and, 320
Montana and, 320
Moscow, Idaho, and, 85
Northern Great Plains and, 321
Santa Clara valley and, 85

Hackensack, N. J.; Oradell dam and, 102
Hardness and; sodium hydroxide and, 432
see Softening
Harrogate, England; waters and; barium and, 437
Hartford, Conn.; services and, 443
streets, wide and; two mains and, 443
Hetch Hetchy; bay crossing division and, 310
progress and, 181, 724
see Moccasin Creek
Highway; *see* Safe Water
Holland; bathing and, 93
water supply and, 315
Hookworm; filtration and, 426
larvae and; permeative ability and, 426
septic tanks and, 426
water and; tropics and, 426
Horton, Kansas; dam and; failure and, 184
Humberstone, Ont.; water supply and, 726
Hydrant; frost protection and; sawdust and, 326
yellow paint and; effectiveness and, 185
Hydraulic Jump; "critical depth" and, 578
discussion and, 720
Hydrocyanic acid; removal and; chlorination and, 434, 566
Hydrogen-Ion Concentration; B. Coli and; limits and, 438
B. Typhosum and; limits and, 438
culture media and; autoclaving and, 436
dilution and, 436
disinfection and, 435
filter operation and, 310, 561
glassware and; interference and, 316
living cells and, 196
oxygen supersaturation and, 434
photosynthesis and, 434
plant and animal distribution and, 317
sea water and, 196
waters, natural, and; pathogens and, 435
range and, 318, 435
see Iron, Corrosion and
Hydrogen Sulfide; *see* Sulfuretted Hydrogen
Hypochlorite; *see* Analysis

Ice; harvest and; reservoirs and, 325
intakes and; safeguarding and, 324
manufacture and; water treatment and, 209
Idaho; Mud Lake basin and, 319
Imperial Valley; ground water control and, 721
Indiana; cross connections and; prohibition and, 101
Indianapolis; flood protection and, 187
Intake; emergency; L. Leman, Switzerland, and, 94
Geneva, Switzerland, and, 94
pipe, cast iron, and, 325
pipe, concrete, and; New Bedford and, 561
Portland, Me., and, 561
see Ice
Iodine; chloride concentration and, 96
Massachusetts and, 178, 560
L. Michigan and, 316
Minneapolis and, 179
New Jersey and, 195
occurrence, natural, and, 440
Rochester, N. Y., and, 93
Saginaw, Mich., and, 96
sea food and, 195
taste, iodoform, and, 727
see Goiter; Iodization
Iodization; discussion and, 322
Minneapolis and, 179
Rochester, N. Y. and; dosage, efficiency and, 93
Iodoform; taste and, 727
prevention and, 727
Iowa; rain and; sulfur content and, 437
stream pollution and, 311
Iron; mains and; incrustations and, 87-90, 732
nodules and, 732
water coloration and, 732
Iron Bacteria; festoons and, 732
incrustations and, 423, 559, 732

prevention and, 559, 565
see Crenothrix
Iron, Corrosion and; atmosphere and, 206
carbon dioxide and; significance and, 205, 438
cast, wrought, and steel and, 575
chlorine and, 436
chromium, nickel, and tungsten and, 575–6
concrete and, 573
Coolgardie, W. A., pipeline and, 561
copper and, 575, 722
dyeing and; difficulties and, 433
factors, fundamental, and, 206
hydrogen-ion concentration and, 310, 318
incrustations and, 423
iron salts and, 318
iron sulfide and, 318
light and, 206
Lowell, Mass., and, 580
manganese and, 575
oxygen and, 436, 438, 735
pitting and; oxygen and, 436, 735
tubercles and; hydrogen-ion concentration and, 310
structure and, 310
present knowledge and; summary and, 99
sea water and, 578
temperature and, 206, 735
see Boiler Corrosion; Corrosion
Iron Hydroxide, Ferric; hydrogen-ion concentration and, 318
Iron Hydroxide, Ferrous, hydrogen-ion concentration and, 318
Iron, Protection and; aluminium and; calorizing and, 316
basic lead chromate and, 197
blue lead and, 197
buildings and, 574
cement and, 559
concrete reinforcement and, 573–4
galvanzing and; tests and, 436
paint and, 100, 197, 431
tar and, 559
Iron Sulfide; corrosion and, 318
water purification, natural, and, 197
Irrigation; Colorado River and, 448
Krian, Perak, and, 563
Ismaïlia; *see* Valve

Java, N. E. I.; super- and dechlorination and, 316
Jersey, Channel Islands; water supply and; microörganisms and, 91–2, 732–3

Kansas; sewage disposal problems and, 442
Kansas City; water supply, new, and, 579
Kearney, Neb.; water supply and; protection and, 97
Kentucky; water supplies and; sanitary rating and, 579
Keighley, England; water supply and, 315
King Institute, Madras; filtration experiments and, 732
report, annual, and, 732
Krian, Perak; irrigation and, 563

La; occasionally neglected for indexing purposes
Law; dams and; New Jersey and, 320; *see* Books, New; Legal Decisions
Lawrence, Mass.; water supply troubles and, 561
Lead; blue; paint and, 197
chromate, basic; paint and, 197
plumbo-solvency and; acidity and, 727, 733
carbon dioxide and, 580, 727, 733
carbonates, and, 728, 733
Lowell, Mass., and, 580
oxygen and, 727, 733
salinity and, 727
silicates and, 728, 733
sodium carbonate and, 315
Leadite; *see* Pipe Joint
Legal Decisions; chlorination patents and, 304
Wisconsin and; stream pollution and, 189
Leipzig, Germany; water supply and, 314
Leman, Lake, Switzerland; intakes and, 94
Leningrad, Russia; ozone disinfection and, 571
Leominster, Mass.; emergency supply and, 562
Lexington, Ky.; water supply and; efficiency, notable, and, 180
Lime; disinfection and, 208, 435, 438, 733
swimming pools and, 208
excess; water treatment and, 727, 733
purification and; advantages and, 208, 433, 727, 733
slaking and, 304
slaking, mechanical, and, 424
softening and; advantages and, 208
solution pipe incrustation and, 304
tropics and, 433
Little River; flood control and, 191

Livestock; *see* Cattle
Locomotive; water treatment and; financial returns and, 208, 437
London, England; chlorination and; aftergrowths and, 199
algae and, 199
permanganate and, 199, 200, 201
taste and, 199, 200, 201
filtration, double, and, 202
prechlorination and, 199
report, annual, and, 199
statistics and, 571
see Taste
London, Ont.; meters and; financial surplus and, 321
Los Angeles; concrete sewer and; open sea construction and, 187
Lowell, Mass.; iron removal and, 580
service pipes and; corrosion and, 580
iron trouble and, 580
lead trouble and, 580
life and, 580
materials tested and, 580
Lubricant; *see* Books, New
Lubrication ; *see* Oil, Lubricating
Lucknow, India; water purification and, 423
Lys River; retting and; hardness and, 431

Madison, Wis.; sewage treatment and, 577
water supply and, 577
Madrid, Spain; water supply and, 311
Magdeburg, Germany; water purification and, 198
Magnesium; water, hard, and; softening and, 208, 211
Magnesium Hydroxide; waste purification and, 577
Main; break and; New York and, 190
faulty; hazards and, 428
shifting bodily and, 724
streets, Pompeiian, and; two mains and, 722
streets, wide, and; two mains and, 188, 443
see Electrolysis; Pipe, Cast Iron; Trenching
Marquette, Mich.; phenol tastes and, 178
Maryland; Bureau of Sanitary Engineering Report and, 315
Engineering Bulletin and, 330
Metropolitan District and, 331
typhoid and, 316
wastes, industrial, and, 315
Melbourne, Australia; weed trouble and, 446–7
L. Mendota, Wis.; bacteriological study and, 573
Meter; banks and; connections and, 722
consumption diminution and, 321, 324
durability and reliability and, 723
setting and, 442
types, various, and, 439
Meter (Electric); connections and; checking and, 567
Methane; ground waters and; significance and, 320, 577
Miami, Fla.; water supply and, 312
Michigan; highways and; safe water and, 323, 428
softening and, 101
L. Michigan; bacteriological survey and, 323
iodine content and, 316
Middletown, Ohio; water supply and, 189
Mine; *see* Acid Water
Minneapolis; iodization and, 179
Minnesota; highway supplies and; signs and, 328
Missouri, Kansas, & Texas R. R.; water treatment, and 326
Missouri Pacific R.R.; water treatment and; savings and, 437
Moccasin Creek; penstocks and, 186
Modelling; pipe plans and; helpfulness and, 569
Mokelumne; water supply and; East Bay Water Co. and, 444
Monel Metal; acid mine water and, 576
ferric salt and, 576
Monroe, Mich.; filtration plant, new, and, 324
Montana; ground water and, 320
Montgomery, Ala.; water supply and, 186
Montpellier, France; water supply and, 95
Montreal; filtration, double, and, 560
filtration, slow sand, and; rates, notable, and, 560
Lachine Canal tunnel and, 210
Moscow, Idaho; ground water and, 85
Motor (Electric); alternating current; principles and, 729
control and, 567
synchronous; changing load and, 567
Mud Lake, Idaho; rise, remarkable, and, 319

Netherlands East Indies; water power and, 563
water supplies and, 571

New Bedford, Mass.; intake, new, and, 561
New Jersey; bathing places and, 571
coast protection and, 445
district, metropolitan, proposed, and, 190, 191
northern; water supply, proposed, and, 312, 584
water works and; plans and, 310, 322
New London, Conn.; water supply and, 188
New Orleans; filter underdrains and, 559
New York City; main and; break and, 190
New York State; code, sanitary, and, 322
Newark, N. J.; water supply and; Wanaque project and, 187
Newark, Ohio; carbonation and; control and, 303
clarifier and; performance and, 303
split treatment and, 302
water supply and, 185, 302
Newport, Mon., England; valves, bronze, large, and, 308
Niagara Falls; recession and, 443
Nile; flow and; gauging and, 90
Nitrate; *see* Analysis

Odor; sewage simulation and, 563; *see* Chlorination; Taste
Ohio; sanitary code and, 322
water purification conference and, 300–4
see Books, New
Ohio River; genesis and; geology and, 195
purification and, 97
Oil; pollution and; livestock and 428, 429
Oil Engine; Bristol, Eng., and; efficiency and, 564
jacket water and; re-cooling and, 330
steam replacement and; economy and, 326
sulfur and; control and, 569
see Diesel
Oil, Fuel; compounding and, 568
diesels and; specifications and, 568
filtration and, 568
storage and; precautions and, 568
straight run and, 568
sulfur and, 568, 569
topping and, 568
Oil, Lubricating; mineral and vegetable and; data, comparative, and, 437
see Lubricant; Lubrication
Omaha, Neb.; coagulant control and; savings and, 580
L. Onega; sulfuretted hydrogen generation and, 431
Ontario; Provincial Board of Health and, 322
typhoid decline and, 322
water purification progress and, 322
Oradell, N. J.; dam and, 102
Oxygen, Dissolved; plants and, 195, 434
removal and, 735
supersaturation and; wind and, 434
Oyster; chlorination and, 95
Ozone; disinfection and; factors, principal, and, 571
Leningrad and, 571
physical data and, 434

Paint; blue lead and, 197
coal tar; tastes and, 331
iron protection and, 100, 197, 431
Paris, France; suburbs and; water supplies and, 584
water supply and; consumption and, 584
Peat; Bradford, Eng., and; trouble and, 193, 571
Pelton Wheel; efficiency, high, and, 725
Pennsylvania; Health Department and; engineering report and, 101
hydrographic data and, 449
typhoid compensation and, 102
water supply commission; report and, 449
water supply statistics and, 102
Permutit; manufacture and, 101
Permutit B; manufacture and, 101
Permutit, Manganese; phenol removal and, 302
special advantages and, 308
Perth, W. A.; filter beds and; collapse and, 565
Peru, Ind.; flood protection and, 723
Phenol; chlorination and; taste and, 178, 302, 325
filter sand and, 302
oxidation and, 302
removal and, 178, 198, 302
filter-beds and, 573, 734–5
flue gas and, 573
naphtha and, 573
soil bacteria and, 735
Philippine Islands; water supplies and, 580
Photosynthesis; hydrogen-ion concentration and, 434
oxygen supersaturation and, 434

Pile; cutting, subaqueous, and, 445
hammer, subaqueous, and, 184
Pipe; fittings *vs.* gas weld; costs and 729
fittings and; ordering and, 720
Pipe, Cast Iron; bronze welding and, 192
factor of safety and; errors and, 721
laying and, 97
leakage and; Columbus and, 722
Pipe, Cement-lined, description and, 720
Pipe Coating; pipeline, steel, and, 578
service pipes and; Lowell, Mass., and, 580
Pipe Cleaning; experience, lengthy and, 560
Pipe, Concrete; concrete-armoured steel and, 426
see Pipe Joint; Pipeline
Pipe, Copper; acid water and, 728
tin lining and, 728
Pipe Deposit; iron incrustations and, 87–90, 423, 559
Pipe, Flow and; bends and; experiments and, 562
formula, new, and; comparison and, 184
formulae, convenient, and, 209, 311
wood-stave and, 321
Pipe Joint; concrete pipe and; copper strip, flexible, and, 209
lead and leadite and, 562, 564
leakage and; hazards and, 428
slip and; leakage and, 444
steel pipe and; expansion joints and, 306
types, various, and, 428
welded; efficiency and, 444, 578, 579, 580
Pipe Pusher; description and, 720
Pipe, Steel; concrete armouring and, 426
slip-joint; deterioration and, 444
welded; satisfaction and, 580
staunchness and, 578
tests and, 579
see Pipeline
Pipe, Wood Stave; Eugene, Ore., and, 192
see Pipeline
Pipeline; concrete; Denver and, 311
leakage, excessive, and; control and, 209
New Bedford and, 561
frost rupture and; weld repair and, 725
steel; Coolgardie, W. A., and; corrosion and, 561
joints and; expansion and, 306
riveting and; hydraulic *vs.* pneumatic, 306
welded; coating and, 578
electric, 444
shipment flat and, 578
tests and, 578, 579
submarine; Vancouver and, 445
tile vitrified, and, 97
water hammer and; damage and, 445
wood stave; construction, rapid, and, 321
freezing and; damage and, 736
lengthy; flow and, 321
Pitometer; sewage measurement and, 191
Pitting; *see* Boiler Corrosion; Corrosion; Iron, Corrosion and
Pittsfield, Mass.; water supply and sewage systems and, 447
Plan; modelling and; helpfulness and, 569
Plumbing; *see* Books, New
Plumbo-solvency; *see* Lead
Pocatello, Idaho; water supply and, 445
Pollution; analysis and, 582
Cambridge, Eng., and; sewage simulation and, 563
streams and; chlorine and, 439
control and, 426
Britain and, 570
deoxygenation and, 309
Iowa and, 311
Ohio and, 300
re-aëration and, 309
self-purification and, 309
studies, quantitative, and, 309
U. S. Public Health Service and, 309
wastes and, 329, 439
Wisconsin and; injunction and, 189
Portland, Me.; intake, new, and, 561
water supply and, 578
Portland, Ore.; dredging, extensive, and, 723
pile-driving, subaqueous, and, 184
Porto Rico; water supplies and, 312
Portsmouth, Va.; sewage system and, 580
water supply and, 580
Poultry; water supply and; permanganate and, 428
Power, generation and; cost and; factors, important, and, 729
progress and; 1925 and, 330
pumping and; cost comparisons and, 566
see Books, New

Prechlorination; London, Eng., and, 199
Magdeburg, Germany, and; control and, 198
slow sand filters and; desirability and, 426
waste prevention and, 425
Preheat; air and; furnaces and; economy and, 433
Price City, Utah; water supply and, 97
Providence, R. I.; tunnel construction and, 443
Public; filtration and, 194
see Books, New
Public Health; *see* Books, New
Pueblo, N. Mex.; flood control and, 724
Pulp Mill; *see* Waste, Industrial
Pump; installation and; regulations, sanitary, and, 447
operation and; care, essential, and, 324
wells, deep, and; turbine type and, 565–6
see Books, New
Pump, Centrifugal; conditions, difficult, and; adjustment and, 181
priming and; vacuum pump and, 721
Pumping; Bristol, Eng., and; efficiency and, 564
efficiency comparisons and, 317
railroads and, 721
wells, deep, and, 426, 563, 565–6
Pumping Plant; pump pit, deep, and; construction and, 736
Purification; aluminate-hypochlorite mixtures and, 581
discussion and, 737
fundamentals and, 312
lime and, 208, 433
literature and; review and, 95
plant design and; trends and, 442
plant operation and; trends and, 442
progress report and, 305, 581
see Coagulation; Disinfection; "Ferrochlore Process; Filtration; Lime; Sedimentation; Softening; Zeolite
Purification, Natural; *see* Self-Purification

Quebec City; water supply and, 560
Questions and Answers; "Power" question box, 569, 731

Radioactivity; French springs and, 192, 440
rocks and, 440
theory and; depth and, 440
sulfur and, 440
temperature and, 440
Railroad; pumping, electric, and; advantages and, 721
softening and; economy and, 327, 577
progress and, 208, 577
see Chicago and Rock Island; Delaware, L. & W.; Locomotive
Rainfall; bird droppings and; analyses and, 428
Britain and; triennium, driest, and, 91
probability methods and, 183
Scotland and, 733
sulfur and; Iowa and, 437
Recording Instruments; water-level, etc., 184
Red Water; ferrous carbonate and, 310
Reservoir; B. Coli and; algae, dead, and, 727, 733
concrete; leakage control and, 311
ice harvest and, 325
irrigation and, 563
microorganisms and; storage ratio and, 323
Shire Oak, Eng.; failure and, 565
reconstruction and, 565
tennis court and; Ponca City, Okla., and, 585
Retting; water quality and, 431
Richmond, Va.; Shockoe Creek sewer and, 724
Rio Grande; storage reservoir and; conditions, improved, and, 189
sand deposition and, 189
Rivet; countersunk; strength and, 725
La Rochelle, France; water supply, new, and, 94
Rochester, Minn.; water tower, concrete, and, 188
Run-off; forests and, 314, 726; *see* Rainfall

Sacramento; consumption, lavish, and, 723
main, long and; shifting and, 724
Sacramento River; salinity and, 320
Safe Water; highways and; Michigan and, 323, 428
Minnesota and, 328
Ohio and, 300
Pennsylvania and 85
Saginaw, Mich.; goiter and iodine and, 96
St. Catharine's, Ont.; water supply, new, and, 193

St. Denis, France; water supply and, 313
St. Louis; water supply, new, and, 579
St. Paul, Minn.; consumption and, 582
costs and, 582
Fridley conduit and, 442
sewers and; tunneling and, 559
softening and, 97
Salton Sea; supplies, regional, and, 319
Sample; depth desired and; device and, 580
San Francisco; sea water and; main corrosion and, 578
water supply and, 181
see Hetch Hetchy
San Salvador; sanitation and, 97
Sand; fineness modulus and, 560
trap, concrete, and; Denver and, 310
uniformity and, 561
Santa Barbara, Cal.; earthquake and, 185, 559
Santa Clara, Cal.; valley and; ground water and, 85
Santa Monica, Cal.; water supply and, 191
Saratoga, N. Y.; baths and springs and, 93
Sawdust; packing and; corrosion and, 326
Sea Water; analysis and, 439
corrosion and; alloys and; resistance and, 731
mains and, 578
equilibrium, atmospheric, and, 435
hydrogen-ion concentration and; biological action and, 196, 434
limits, alkaline, and, 196
range, normal, and, 196
salinity gradients and, 196
Sedimentation; baffles and, 560
basins and; return bends and, 192
flow velocity and, 313
Selenium; bacteria and; reduction indicator and, 207
Self-Purification; bacteriophage and, 439
studies, quantitative, and, 309
underground processes and, 197
Service Pipe; Hartford, Conn., practice and, 443
Sewage; chlorination and, 734
treatment and; United States and, 579
Sheffield; dam and; failure and, 186
Shore Erosion; N. J. and; protection and, 445
Silk; manufacture and; water purity and, 308
Silt; erosion and, 724
Modder River and, 423
sedimentation and; flow velocity and, 313
Sludge; drying and; glass houses and, 442
Sluice; Stoney gates and; estimating and, 736
Soda Ash; *see* Sodium Carbonate
Sodium Aluminate; coagulation and, 300–1
softening and, 301, 326
Sodium Carbonate; plumbo-solvency and, 315
Sodium Hypochlorite; disinfection and; radiation and, 205
Sodium Sulfate; pitting and, 305
Sodium Sulfite; de-chlorination and, 316
Softening; chemistry and, 427, 586
clay manufactures and, 581
Columbus, Ohio, and, 427, 737
cost and, 427, 586
economy and, 472, 586, 737
Groveland, N. Y., and, 326
industrial supplies and, 316, 572, 737
lime and; advantages and, 208
Michigan and; survey and, 101, 194
mine drainage waters and, 314
Newark, Ohio, and, 302
permutit and, 433, 737
railroads and, 327, 429, 585
St. Paul, Minn., and, 97
sodium aluminate and, 301, 326
United States and; history and, 585
zeolites and, 319, 737
see Boiler Feed Water; Doucil; Permutit; Zeolite
Soil; B. Coli and, 441
condensation and, 314
evaporation and, 437
Sounding; inshore; methods and, 90
samples and, 580
South Pittsburgh, Pa.; carbonation and, 303
South Staffordshire, Eng.; district, extensive, and, 565
supply statistics and, 565
Spavinaw Creek; aqueduct and, flow tests and, 190
Grand River crossing and, 185
Spillway; gates, automatic, and, 181
Oradell, N. J., dam and, 102
profile, ogee, and, 84
side channel; theory and design and, 98
velocity control and, 84

Split Treatment; Newark, Ohio, and, 302
Spring; mineral, health resort, 93
Springfield, Mass.; slow sand plant extension and, 582
Standards; advisory committee and; report and, 328
Tallin, Esthonia, and; guarantees, stringent, and, 726–7
Standpipe; fire protection and, 311
State Sanitary Engineers' Conference; ground water supplies; control and, 446, 447
Statistics, water works and; Eng. News-Record and, 735; *see* Books, New
Staunton, Va.; watershed protection and, 184
Steam; carbon dioxide and oxygen and, 572
Steel; structural; columns and; report and, 735
high strength and, 722
Sterilization; media and; hydrogen ion concentration adjustment and, 207; *see* Disinfection
Stoker, Mechanical; efficiency, high, and, 729
savings, remarkable, and, 567
underfeed; wood refuse and, 330
Storage; ratio; microörganisms and, 323
surface waters and, 323
Storage Batteries; electrolyte and, 730
Stream; control and; *see* Books, New
gauging and; *see* Books, New
surface slopes and; backwater curves and, 191
Stream Pollution; *see* Pollution
Strontium; brines, natural, and, 317 *see* Analysis
Structure, Steel; members and; utilizable capacity and, 310
Stuttgart, Germany; water purification and, 429
Sulfite Liquor; *see* Waste, Industrial
Sulfuretted Hydrogen; chlorination and, removal and, 434, 566
Lake Onega and; conditions and, 431
Superchlorination; *see* Chlorination
Surge; chamber; lining cracks and, 720
swirling and; controlling and, 721
Sweden; water works practice and, 570
Swimming Pool; attendance, average, and, 427
chlorination and, 734
construction and; recommendations and, 427
construction, new, and, 93
disinfection and; chloros and, 312
lime and, 208
Edmonton, Alta, and, 194
Frankfurt a. M., Germany, and, 199
Hague, Holland, natatorium and, 93
New Jersey and; A. P. H. A. standards and, 571
control and, 571
recirculation and, 92, 193, 199
St. Helen's, Eng., and, 193
Vienna, Austria, Amalionbad and, 94
Sydney, N. S. W.; valves, Johnson-Boving, large, and, 210
Synchronous; *see* Motor (Electric)
Syracuse, N. Y.; flood protection and, 185

Tallin (Reval), Esthonia; filtration plant, new, and, 726
guarantees, stringent, and, 726
Tampa, Fla.; water supply, new, and, 585
Tank; concrete; durability and, 326
Rochester, Minn., and, 188
steel, large; moving and, 325
wood stave; collapse and, 187
Taste; chlorine-phenol; aëration and, 201
ammonia and, 201
atmosphere and, 178, 200, 201, 424, 727, 733
dilution and, 201, 424
iodoform and, 727
light and, 201
paint, coal-tar, and, 331
permanganate and, 199, 200, 302, 727
prevention and, 201, 424
superchlorination and, 200, 201, 300
wastes and, 300, 302, 325, 572
Temperature; depth and; measurement and, 99
Terre Haute Water Works Co.; customer ownership and, 311
Theodosia, Crimea; condensers, atmospheric, ancient, and, 210
Thermometer; adjustment, accurate, and, 84
Thiem; well systems and, 314
Tin; pipes and; lining and, 728, 734
Toledo, Ohio; water supply, new, and, 442
Toronto, Ohio; coagulation, double, and, 303

Trenching; ditcher, small, flexible, and, 723
mechanical; cost and, 562, 564
Tropics; algae and; control and, 313
B. Coli and; types, fecal and non-fecal, and, 312
lime and, 433
slow sand filters and, 425
water supplies and; difficulties and, 571
worms and protozoa and, 426
Trout; fry and; algae and, 733
Tunbridge Wells, Eng.; deep well supply, new, and, 563
Tunis; aqueduct, Roman, and, 94
Tunnel; Alouette-Stave Lake, B. C.; construction and, 725
Florence Lake, Cal., and; construction and, 181
Holland vehicular; lining and, 723
irrigation; earth and clay and, 189
lining and; cement gun and, 185
Montreal water supply and; Lachine canal and, 210
pressure gallery construction and, 584
Providence, R. I., water supply and, 443
sewers and; St. Paul and, 559
Wanaque project and, 190
Turbidity; Baylis turbidimeter and, 561
filter wash and, 561
Turbine, Steam; large; design and, 730
Turbine, Water; arrangement, standard, and, 90
design, new, and, 184
head, high, and; efficiency and, 726
see Books, New
Typhoid; Ægion, Greece, and; prophylaxis and, 425
bathing beaches and, 582
carrier and, 430
compensation and; Pennsylvania and, 102
cross-connections and; Niagara Falls, N. Y., and, 329
diarrhea outbreaks and, 323
Maryland and, 316
vacation hazard and, 195

Ultra-violet Radiation; sodium hypochlorite and, 205
sterilization and, 198
lamp requirements and, 198
Underdrain; *see* Filtration, Rapid Sand
Utility; *see* Books, New

Vallisneria Spiralis: Melbourne, Australia, and; trouble and, 447
Valve; bronze; large equilibrium ball type, 308
care and; hints, practical, and, 726
closing, electric, and, 723
control, automatic, and, 186
Ismaïlia type and; advantages and, 563
Johnson-Boving type; Sydney, N. S. W., and, 210
medium pressure; type, new, and, 721
Vancouver, B. C.; pipeline, submarine, and, 445
Vaud, Switzerland; water supplies and, 426
Venturi Flume; discussion and, 423
improved; measurements and, 98
Venturi Meter; obstruction and; correcting error and, 730
Vessel, Navigating; water supplies and; control and, 328
Vicksburg, Miss.; water supply and; pump pit, deep, and, 736
Victoria, B. C.; water supply and, 209
pipeline, concrete, and; leak, excessive, and, 209

Wanaque; *see* Dam
Washington, D. C.; water supply, new, and, 180
Waste, Industrial; ammonia stills and, 573, 734
coke ovens and; stream pollution and, 329, 434, 566
dairy; treatment and, 574
distillery; treatment and, 178
lignite briquets and; treatment and, 577
Maryland Bureau of Sanitary Engineering and, 315
phenol removal and, 573
stream pollution and, 439
sulfite liquor and; difficulties and, 207
tannery; chlorine and, 734
tastes and (*see* Taste), 300
treatment and; chlorine and, 439, 566
clay and, 439
gas and, 440
problems and, 331
Water, Carbonated; bacteriological study and, 198
Water Hammer; elimination, automatic, and, 186
vitrified pipe and; damage and, 445

Water Power; Netherland East Indies and, 563
Stave Lake, B. C., development and, 725
tests, standard, and, 564
United States Geological Survey and, 722
see Books, New; Flow; Pelton Wheel; Turbine, Water
Water Supply; Canada and; statistics and, 579
condensation, atmospheric, and; ancients and, 210
grading and, 178, 323
history, early, and, 101
United States and; statistics and, 579
see Books, New; Water Works
Water Supply Finance; customer ownership plan and, 311
main extension and; assessments and, 191, 323
Water Supply, Rural; Britain and, 210; *see* Books, New
Water Weed; control and, 429
Melbourne, Australia, and, 446
Water Works; clear water reservoir and; location and, 561
statistics and; Eng. News-Record and, 735
trends, present-day, and, 194
see Water Supply
Water Works Accounting; *see* Depreciation
Watershed; forestation and; advantages and, 726
Britain and, 726, 734
New York State and, 192
forests and; protection, sanitary, and, 184
Waterville, Maine; pumps, centrifugal, and, 181
Weld; electric; cast iron and, 434; *see* Pipe, Steel; Pipeline
Well; Arabia and, 317
coastal; salt contamination and, 319
construction and, 449
deep; pumping installation and, 426, 563, 565–6
depth record and, 424
France and; American methods and, 584
gravel wall and; flow, increased, and, 559
pump installation and; control, sanitary, and, 447
safe water and; limestone and, 85
Pennsylvania and, 85
sand and; gravel wall protection and, 186
screens and, 442
Thiem system and, 314
Wheeling, W. Va.; consumption and; metering and, 324
filtration plant, new, and, 324
Whitehall, N. Y.; water supply and, 188
Wilmington, N. C.; water supply and, 181
Woonsocket, R. I.; water supply and, 447
Wood; protection and, 574
structures, submerged, and; advantages and, 561
Worcester, Mass.; water supply, additional, and, 578

Year Book; *see* Books, New
York, Pa.; pumping system and, 180

Zeolite; acid water and, 314
water purification and, 100
see Doucil; Glauconite; Permutit; Permutit B; Softening
Zinc; Devil's Lake, N. D., and; toxicity and, 195

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Kirchoffer, William Gray	6
Leadite Company, Inc., The	cover 4
Lee, Charles H.	6
Leopold, F. B.	6
Levitt Ferguson Co.	54
Lock Joint Pipe Company	39
Ludlow Valve Manufacturing Company, The	20
Mabbs Hydraulic Pkg. Co.	32
Mathieson Alkali Co.	10
Maury & Gordon	6
McWane Cast Iron Pipe Co.	18
Metcalf and Eddy	6
Mueller Company	25
Mullergren, Arthur L.	6
Multiplex Mfg. Co.	12
Murray Iron Works Company,	cover 3
National Cast Iron Pipe Company	31
National Meter Company	36
National Water Main Cleaning Company	14
Neptune Meter Company	43
Nicoll, B. & Co.	33
Paradon Engineering Co.	46
Pearse, Greeley & Hansen	6
Penstock Construction Co.	8
Permutit Company	48
Pitt Construction Co.	7
Pittsburgh Meter Company	47
Potter, Alexander	6
Potts, Clyde	7
Rensselaer Valve Co.	37
Ross Valve Manufacturing Company	32
Savage, W. J. Co., Inc.	9
Scofield Engineering Co.	7
Simplex Valve and Meter Co.	21
Smith, A. P., Manufacturing Co.	29
Sullivan Machinery Co.	56
Taylor, W. P., Co.	44
Thomas, Arthur H., Co.	42
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Union Water Meter Company	50
United States Cast Iron Pipe and Foundry Company	1
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Wallace & Tiernan Co., Inc.	19
Wanted Positions	8
Warren Foundry and Pipe Company	12
Weston and Sampson	7
White & Co., Gilbert C.	7
Wiggin, Thos. H.	7
Williamson, S. B.	7
Winkler, Isaac, & Bro.	44
Wood, R. D. & Co.	cover 2
Worthington Pump and Machinery Corp.	23

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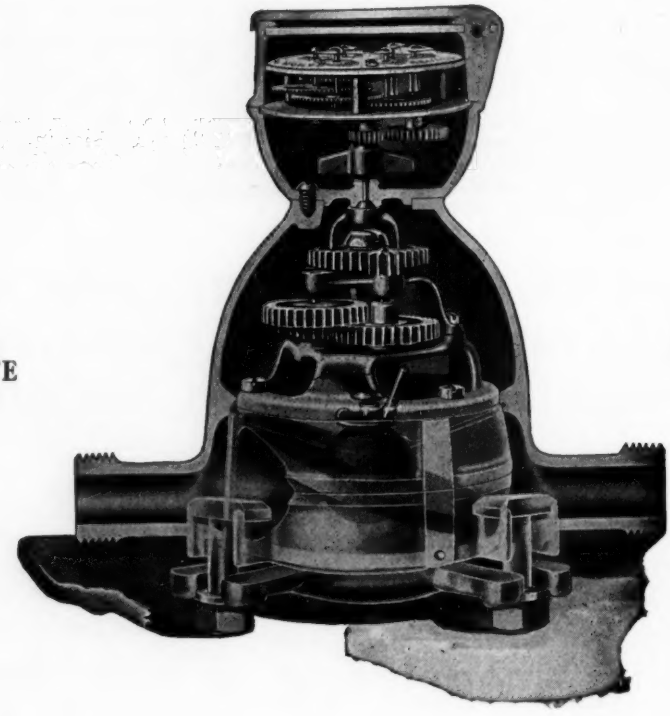

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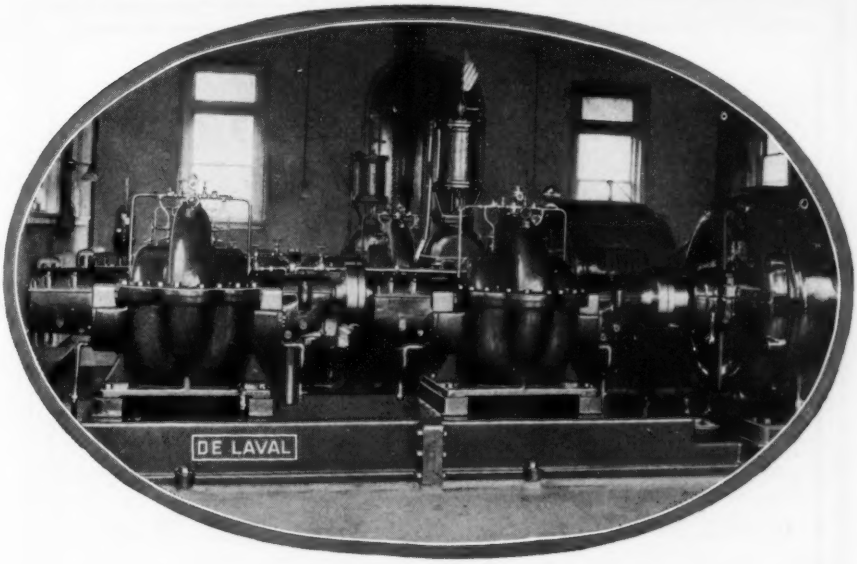

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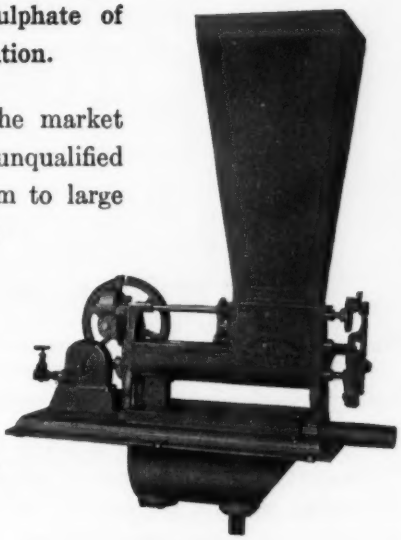

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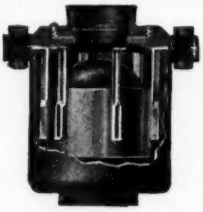

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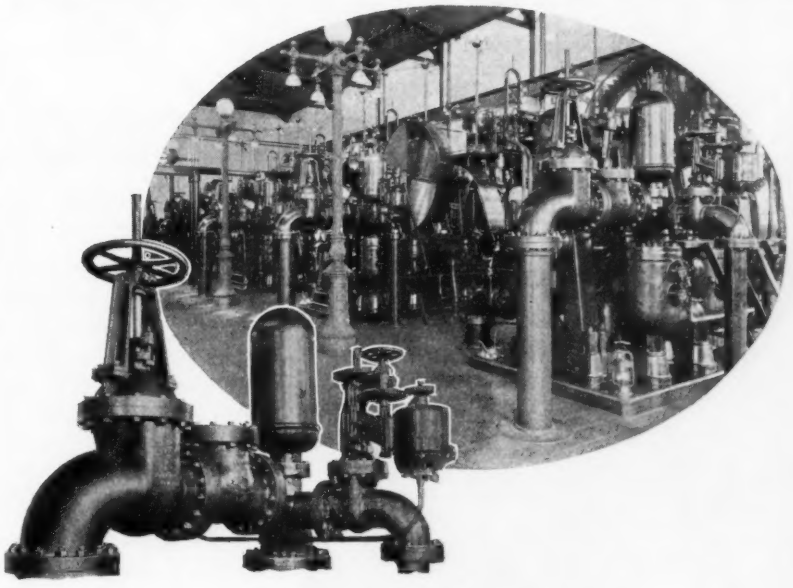

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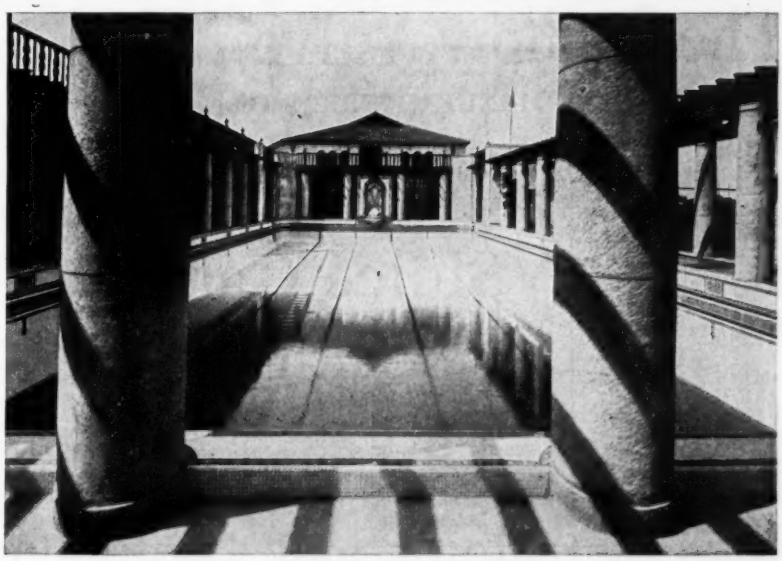

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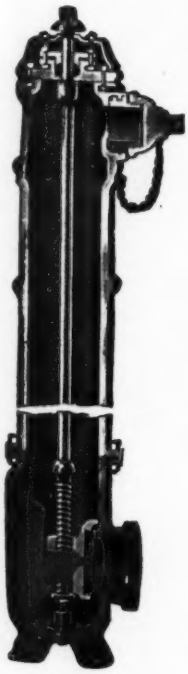

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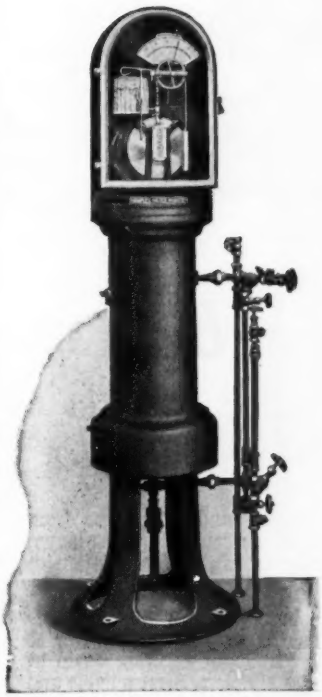


Simplex Meter Register

Every up-to-date water works manager holds it essential to know at all times the efficiency of his plant. If pumping, he must know the fuel consumed and the amount of water pumped. Pump counters are unreliable, on account of pump slip varying from zero to 40% in reciprocating pumps, and on centrifugal pumps they are inoperative. If the supply is by gravity, he must know the quantity of water flowing.

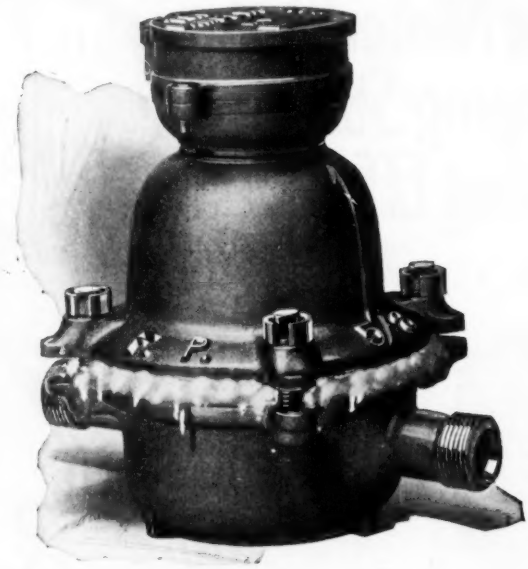
Simplex meters provide for either one of these conditions by giving a continuous record of the flow of water. It is simple, rugged, reliable and accurate from the maximum down to 5% of the maximum flow, without material loss of pressure.

Interesting data on the "Simplex Venturi Tube Meter" sent upon request

SIMPLEX VALVE AND METER CO.

Manufacturers of Meters for Water, Sewerage and other liquids, Rate Controllers, Automatic Air Valves, Regulating Valves, and Hydraulic Apparatus of Special Design

6759 UPLAND STREET **PHILADELPHIA, PA.**



FROZEN!—but not damaged

Here is an actual photograph of a LAMBERT Frost-Proof Meter which has been frozen to an extent that would put the ordinary meter completely out of commission.

This is made possible by a patented, non-corrosive yielding bolt device which allows the upper and lower casing, disc chamber and gear train to part without damaging the meter in any way. Five minutes' labor the only repair cost.

The expense and annoyance from frozen water meters can be eliminated for all time through the installation of the LAMBERT Frost-proof.

It has been proved that the LAMBERT is the easiest water meter to take apart and put together again as well as the simplest, most reliable and accurate.

If you are interested in other types of meters, we make one for every requirement.

THOMSON METER CORPORATION

SALES OFFICE, 50 E. 42nd STREET NEW YORK CITY, N. Y.

LAMBERT FROST PROOF METERS

Worthington Water Meters

The Worthington meter line is complete. It includes a meter for every possible service and condition.

Disk Meters—both frost-proof and for warm climates

Turbine Velocity Meters

Compound Meters

Hot-water Meters for boiler-feed lines

Oil Meters

Stocks of meters and parts are carried in our branch houses in all parts of the country. Write for bulletins.

The Worthington Waterworks Line

Pumps, steam and power, reciprocating and centrifugal

Pumping Engines, horizontal cross-compound and vertical triple expansion, crank and fly-wheel and direct-acting

Condensing Apparatus, surface, jet, barometric

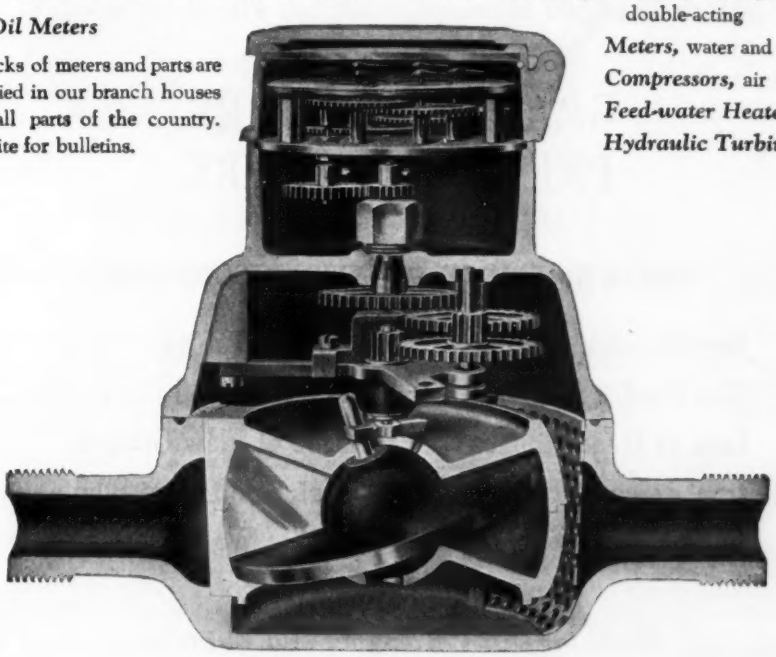
Diesel Oil Engines, horizontal and vertical, two-cycle and four-cycle, single and double-acting

Meters, water and oil

Compressors, air

Feed-water Heaters

Hydraulic Turbines



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BRANCH OFFICES IN 24 CITIES

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Successor To

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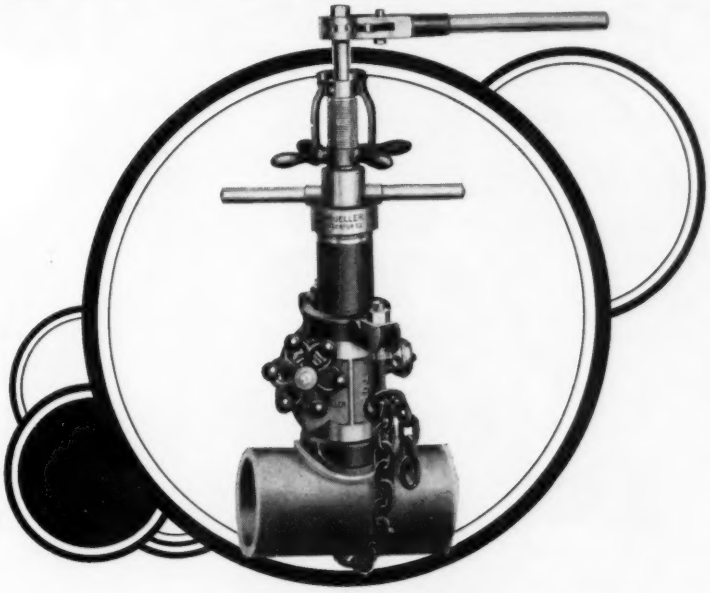
ORIGINATORS OF MECHANICAL FILTRATION



Better, quicker tapping

with the *improved* Mueller Tapping Machine *B*

Mueller engineers have designed ***new*** efficiency in the Mueller Water Tapping Machine "B," shown above. Embodying all the recent Mueller improvements, this machine sums up all that is best in tapping machine construction. The ease and speed with which it taps a main and inserts a corporation stop is nothing short of a revelation to those observing its operation for the first time.

You cannot afford to do your tapping with a machine of less efficiency. The improvements in the Mueller "B" will speed up your work. You can effect greater savings in time and labor. Greater economy in tapping costs will soon pay for the cost of the machine.

The Mueller Tapping Machine "B" makes taps and inserts stops from one-half to one inch in pipe under pressure. It makes taps alone from one-half to two inches in open or dry pipe. When used with Mueller Corporation Stops, with the superior Mueller thread, a permanent non-leaking joint is assured.

We will make a liberal trade-in allowance on your old Mueller model. Write for details today.

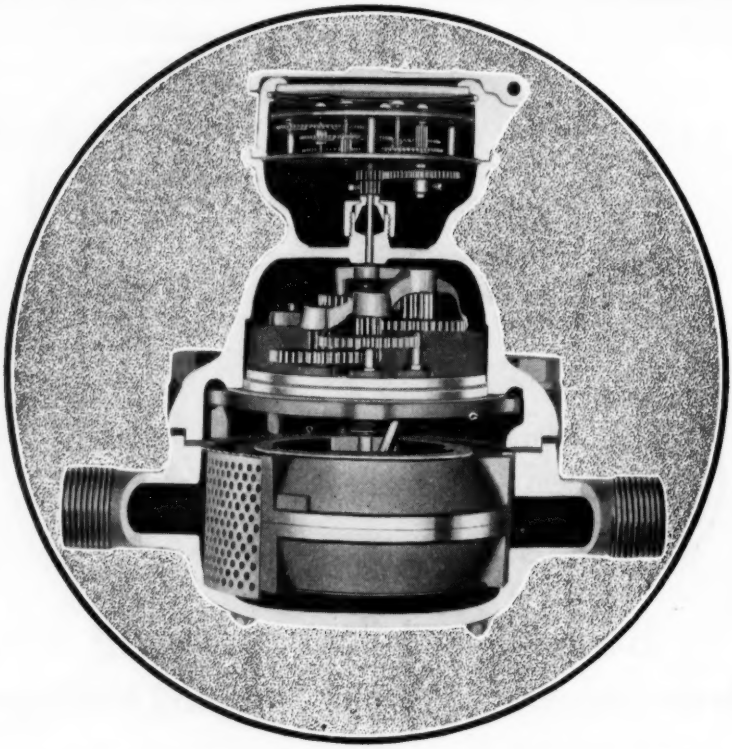
MUELLER CO.
(Established 1857)

Factories: Decatur, Illinois; Port Huron, Michigan.

Canadian Factory
MUELLER, Limited, Sarnia

Branches
New York, San Francisco, Los Angeles

MUELLER
Reducing and Regulating Valves



BADGERS LEAD!

City after city is standardizing on Badger Meters. But only after careful study—careful test—careful comparison of maintenance costs.

This ever-increasing popularity is gratifying—but not surprising. For Badgers are built up to the highest standards known to meter manufacturers—manufacturers who build nothing else.

Take for example the Model "SC" shown above—it is different from ordinary meters of this type and size. It is *designed* for a certain service. Its sturdy construction—heavy bronze housing—in every particular, a *lifetime meter.*

All Badger types embody advantages of design and construction that permit them to stand out prominently in the general meter field. They are built to give long years of service—accurate registration—lowest maintenance cost—practical design—simplest construction—and are *built to last.*

There are interesting reasons why many cities have been Badger-equipped. Let us tell them to you—show you what Badger Meters will do on your lines.

Badger Meter Manufacturing Company

Milwaukee, Wisconsin

BRANCH OFFICES—
1621-39 Fifteenth Street,
DENVER, COLO.
4040 Arcade Bldg.,
SEATTLE, WASH.

BADGER METERS

BRANCH OFFICES—
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367 Fulton Street,
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414 Interstate Bldg.,
KANSAS CITY, MO.

GOLDEN-ANDERSON

Patent Automatic Cushioned Controlling Altitude Valves

We have enlightened many a water user in municipalities, in industrial plants and on railroads, as to the **adaptability** of these Golden-Anderson Valves, and as to their function of SAVING, and of eliminating troubles.

For automatically maintaining Uniform Stage of Water in Tank, Reservoir or Standpipes. Doing away with the annoyance of Freezing and Float Fixtures inside or outside of Tanks.

"Three Ways of Closing These Valves:"

1st—Automatically, by water
2nd—By Electricity, if desired
3rd—By Hand

May also be arranged to automatically close when a break occurs in the mains. When necessary they may be so connected as to "work both ways" on a single line of pipe.

No valves or fixtures inside or outside.

Sizes to 30 in.

Remember!

"HOSTS OF REFERENCES"
Valves cushioned at all times by air and water
No water hammer or bursting mains

"Made with stop starter attachment for centrifugal pumps"

GOLDEN-ANDERSON
Automatic Cushioned Water Regulating Valves

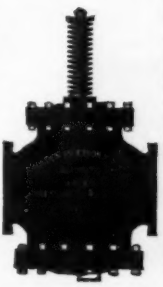
for high or low pressure service are a *necessity* for modern water works and railroads.

Positive in action and perfectly cushioned both in opening and closing.

Will maintain a constant pressure regardless of the volume of the initial flow.

When fitted with electrical attachment valve can be instantly opened to full area from any number of distant points, thus insuring full pressure in case of fire, etc.

Sizes to 30 in.



GOLDEN-ANDERSON
Patent Automatic Cushioned Controlling Float Valves

They carry a constant water level in feed water heaters by perfectly controlling the flow of makeup water.

Operated by protected enclosed copper float.

Cushioned by both air and water.

Operate without hammering, sticking or chattering. No metal to metal seats. Made angle or straightway.

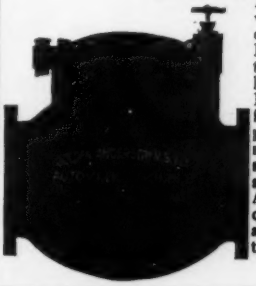
Sizes 1 in to 30 in.

GOLDEN-ANDERSON
Pat. Automatic Cushioned Water Float Valves

1. Automatically Maintain Uniform Water Levels in Tanks, Standpipes, etc.
2. Instantly Adjusted to Operate Quickly or Slowly.
3. Floats Swivel to any Angle—Most Satisfactory Float Valves Known.
4. No Metal-to-Metal Seats — No Water Hammer or Shock.
5. Cushioned by Water and Air.

Sizes to 30 in.

GOLDEN-ANDERSON
Patent Automatic Double Cushioned Check Valve



Automatically prevents reverse flow of pressure.

Perfectly cushioned to prevent shock or hammer.

Especially adapted for water works to prevent disastrous reverse flow of pressure due to pumps stopping.

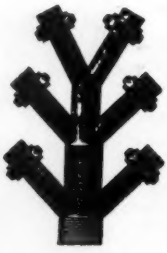
Arranged so that quick or slow operating may be obtained.

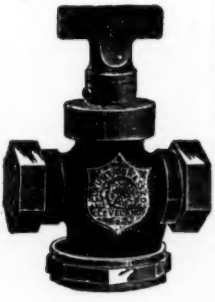
Sizes to 30 in.
Angle or Globe

Golden-Anderson Valve Specialty Co., 1215 Fulton Bldg., Pittsburgh, Pa.

"GLAUBER" BRASS GOODS

NEVER FAIL TO MAKE A GOOD IMPRESSION - ONE THAT LASTS





GLAUBER BRASS MFG. CO.

Cleveland, Ohio

The A. P. Smith Manufacturing Company

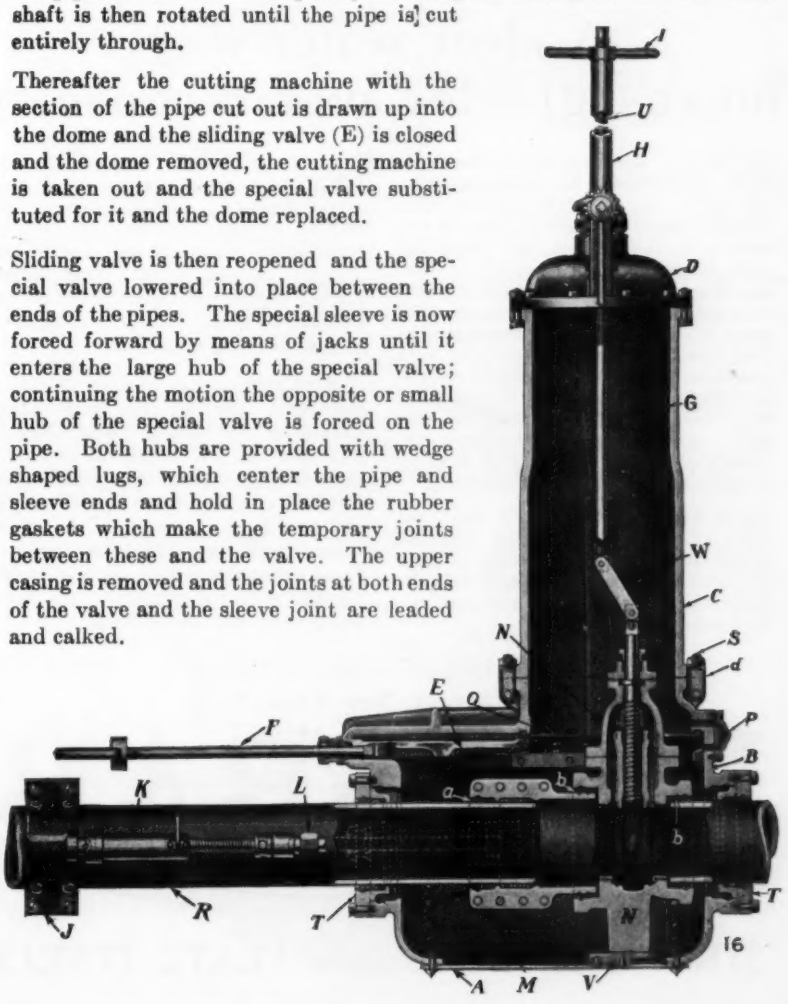
East Orange, New Jersey

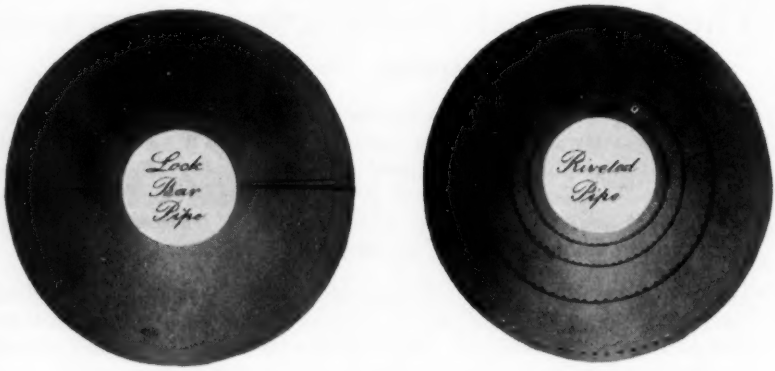
Manufacturers of Water Works Specialties, one of these specialties shown herewith, namely a Machine for inserting 4″, 6″ and 8″ valves in existing straight lines of pipe under pressure. The machine is made in other sizes as follows: No. 2 for inserting 8″, 10″ and 12″ valves, No. 3 for inserting 14″, 16″, 18″ and 20″ valves, No. 4 for inserting 24″ horizontal valves and we are now designing a machine for inserting 30″ valves.

The pipe is cut about one-half through and the special sleeve is then bolted around the pipe, the end of the sleeve being placed within a fraction of an inch of the cutting tool; the Inserting Machine is then attached around the pipe and the sleeve completely enclosing the cutting mechanism. The shaft is then rotated until the pipe is cut entirely through.

Thereafter the cutting machine with the section of the pipe cut out is drawn up into the dome and the sliding valve (E) is closed and the dome removed, the cutting machine is taken out and the special valve substituted for it and the dome replaced.

Sliding valve is then reopened and the special valve lowered into place between the ends of the pipes. The special sleeve is now forced forward by means of jacks until it enters the large hub of the special valve; continuing the motion the opposite or small hub of the special valve is forced on the pipe. Both hubs are provided with wedge shaped lugs, which center the pipe and sleeve ends and hold in place the rubber gaskets which make the temporary joints between these and the valve. The upper casing is removed and the joints at both ends of the valve and the sleeve joint are leaded and calked.





A clear water-way means greater water capacity

LOCK-BAR steel pipe has a smooth interior unobstructed by rivets and has a slightly better carrying capacity than cast-iron pipe. Riveted pipe is less smooth in the interior, the projecting rivets increasing the friction of the flowing water, and also the numerous joints with either in-and-out joints or with taper joints. For these reasons riveted steel pipe carries from 10 to 15 per cent less water than LOCK-BAR pipe or cast-iron pipe. In comparing riveted pipe with LOCK-BAR pipe and cast-iron pipe, a riveted pipe should be taken with a sufficiently greater diameter in order to carry as much water as the others.

LOCK-BAR STEEL PIPE has been held by eminent engineers, including among others, J. Waldo Smith, Clemens Herschel and Allen Hazen, to have ten to twenty per cent less resistance than riveted steel pipe.

It will be readily understood why LOCK-BAR pipe has so much more carrying capacity. Obstructions to flow, causing friction and reducing capacity are practically eliminated. The absence of obstruction and smooth inner surface further eliminates opportunity for the building up within the pipe of deposits to restrict the pipe area.

Riveted pipe is open, to some extent, to objections, due to the obstructions caused by rivet heads, but LOCK-BAR pipe has but one-fourth the number of circular seams that riveted pipe has and but 40% of the joints of a cast-iron pipe of 12-foot length. Moreover, the smooth longitudinal seams have no rivets to furnish easy attachment for foreign matter and to create eddies and the resultant friction and loss of head.

EAST JERSEY PIPE COMPANY
7 Dey Street, New York, N. Y.

LOCK-BAR

Before Closing

STRONG AS THE PLATE ITSELF

EDSON

DIAPHRAGM
PUMP SPECIALTIES

Hand and Power Outfits

HEAVY DUTY One or Two Pump UNITS
with 3-inch or 4-inch Suction

Insist on GENUINE EDSON Pumps, Suction Hose, Diaphragm with Bead, etc.

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IS MADE RIGHT

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BIRMINGHAM, ALABAMA

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We are featuring our 2" Bell and Spigot Cast Iron Service Pipe in 6' lengths with prepared joint. Write or wire us for information.

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Automatic Pressure Regulating Valves

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DOUBLE ACTING ALTITUDE
REDUCING RELIEF

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Water Works Engineers

Do You Want a Packing that will NEVER Cut or Score Your Rods, Shafts, or Plungers, and Will Last For Years?

Then send us an order for the MABBS RAWHIDE PACKING which never becomes hard or glazed, and will save you power and money. Any size put up in standard tin pails of 5-10-25 and 50-lbs. and in kegs and barrels of 100 and 200-lbs. Price $2.00 per lb.

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DIAMOND SODA ASH

Guaranteed over 99% Sodium Carbonate
Conforms to Every Requirement of Municipalities and Industrial Plants Maintaining Water Softening Equipment.
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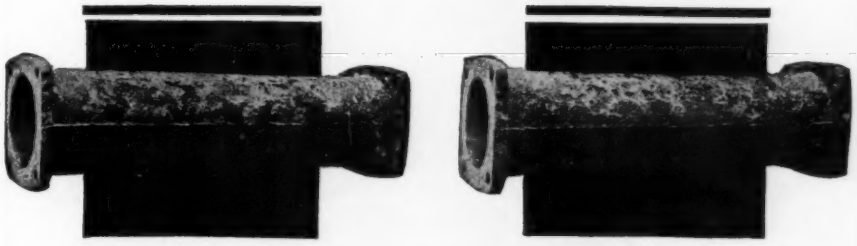
DIAMOND ALKALI COMPANY
PITTSBURGH, PENNA.

French Cast Iron Pipe praised by American Pipe Makers



Still in Service After 250 Years

These two sections of pipe, taken from the centuries-old cast iron pipe installation at Versailles, have been brought to this country for exhibit purposes, and are on display at the offices of B. Nicoll & Company, Inc., New York.

As an outstanding example of cast iron pipe superiority, American pipe makers point to the cast iron pipe installed at Versailles in the reign of Louis XIV. The French knew how to make pipe then, and they know how today.

Pont-à-Mousson Cast Iron Pipe is made in France for America in accordance with A. W. W. A. specifications by the famous Societe Anonyme Des Hauts Fourneaux et Fonderies de-Pont-à-Mousson, one of the largest pipe makers in the world.

Widely used by American municipalities and other American users, Pont-à-Mousson is worthy of your serious consideration.

Our quotations will interest you. What are your requirements?

* "P-à-M" Pipe
Immediate shipment. All Sizes. Large Stocks ready for delivery in American ports within thirty days.

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CAST IRON PIPE AND FITTINGS
A. W. W. A. Specifications

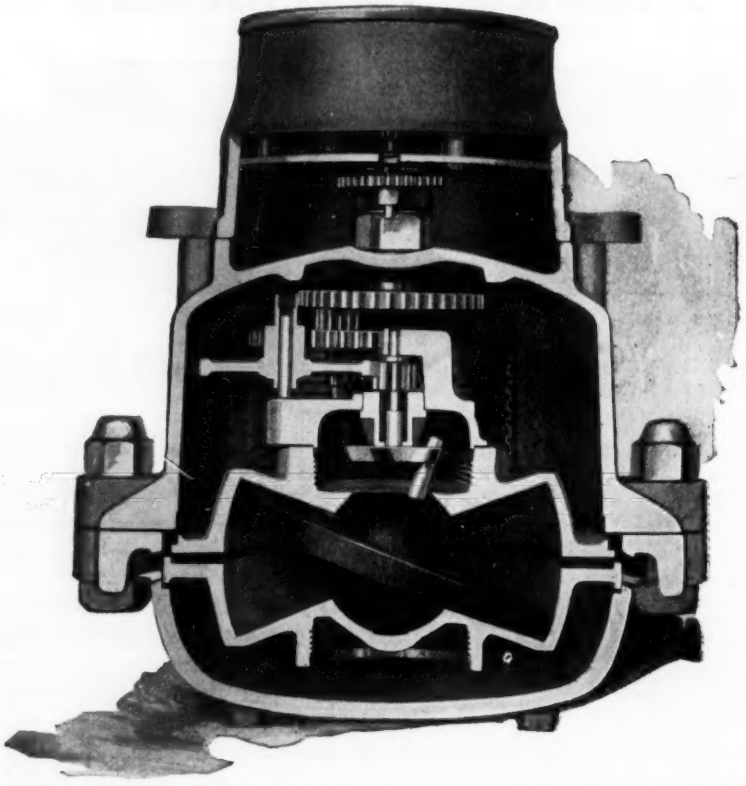
B. Nicoll & Company, *Incorporated*
General Agents in the United States

New York, 294 Madison Avenue, (at 41st St.) San Francisco, Rialto Building

AMERICAN AND NIAGARA

WATER METERS

WITH BREAKABLE FROST BOTTOMS (Patd.)



This sectional view shows a $\frac{5}{8}$ inch or house size meter cut at right angles to the pipe line. The breakable frost bottom has been broken by a freeze up.

NOTE:

1. How the breakable section of the bottom is entirely inside and independent of the meter flange. This allows the six flange bolts to be drawn directly up on the gasket. Meter is tight on highest pressures.
2. How the breaking of the frost bottom immediately releases the measuring chamber. No warping.
3. How the submerged gears can remain fixed in the ice, while their bearing shafts move downward. No breakage.

These and other points described in large illustrated catalogue. Write for your copy.

Write for catalog and prices

BUFFALO METER CO.

2914 Main St. **BUFFALO, N. Y.**

Niagara and American meters comply in all respects as to accuracy and capacity with the Standard Specifications of the American Water Works Association.

United States Cast Iron Pipe is used in Buffalo's great filtration plant.

Waterworks engineers prefer Cast Iron Pipe on account of its permanence.

This quality is especially valuable where intricate installations are necessary such as in this great filtration plant.

The length of life of the Cast Iron Pipe has not yet been determined. The first Cast Iron Pipe in this country was laid down over a hundred years ago and is still in use

Our engineers will be glad to cooperate with you on any problem involving pipe, castings or fittings.

United States Cast Iron Pipe and Foundry Company

General Offices:
Burlington, New Jersey

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WATER METERS

the product of an experience covering over half a century

Well Designed Accurate

Carefully Built Substantial

NASH TYPE K

This is a disc meter of unusual merit, with every feature that careful test and experiment have proved to be worth while.

All bronze construction. Simple design. Easy to take apart without removing from the service pipe. Breakable flange washer —a cheap and effective frost protection feature.

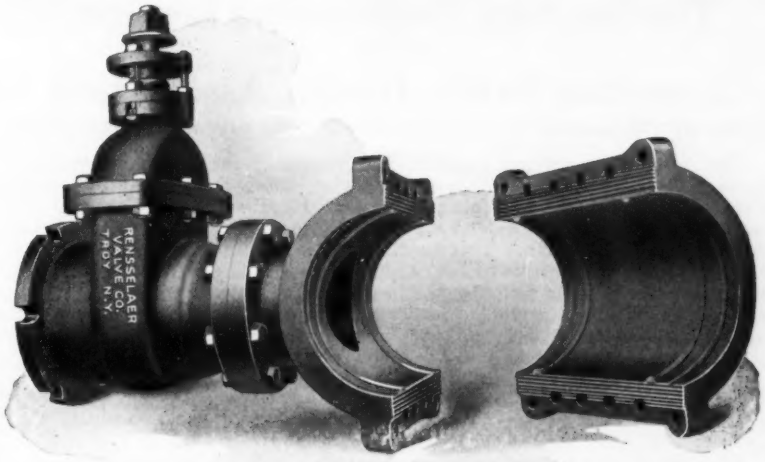
Nash Type K is also furnished in a "Dixie" model, without the frost washer, for use in localities where frost damage is not probable.

We shall be glad to send on request Booklet 200, fully describing and illustrating Nash Type K.

NATIONAL METER COMPANY

299 BROADWAY, NEW YORK

CHICAGO BOSTON CINCINNATI ATLANTA SAN FRANCISCO LOS ANGELES



SOME of the POINTS OF SUPERIORITY of RENSSELAER TAPPING SLEEVES

Require ***less lead*** *for Calking*
Easier to center *on pipe* ***before pouring***
Give ***Extra Pipe Protection***
Bolts require ***No Iron Washers***
Each Size *carefully* ***designed for its Working Pressure***
Can be used with all Standard Tapping Machines

Rensselaer Tapping Sleeves are the only Sleeves on the market which are built with two Raised Rings which are a part of the Sleeve Casting itself. These Rings are used as Stops for the Hemp or Jute against which the Lead is poured to make the joint. In other types of Sleeves, without Rings, the Lead, when poured, fills entire space up to point at which cut is made.

The Raised Rings also permit easier centering of Sleeves on Pipe, also permit revolving Sleeve on pipe making it easier to tighten nuts on bolts which connect the two halves of the Sleeve.

The Bolting Flanges on all Sizes of Rensselaer Sleeves are made the full length of the Sleeve, permitting a greater number of bolts to be used back of point calked, giving greater protection to pipe at point where piece is cut out. This is especially important as in some cuts a hole nearly one-half the size of pipe is cut away.

BOOK No. 11 GIVES FURTHER PARTICULARS

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PITTSBURGH, Oliver Bldg. NEW ENGLAND, C. L. Brown, Northboro, Mass.

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Definitions for Sewerage and Sewage Disposal Practice; Water Supply and Purification, Report of the Committee; Values in the Control of the Environment; Sewage Analysis and its Interpretations; Bathing Places, Report of the Committee; Incinerator Specifications and Contract Tests.

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The American Public Health Association,
370 Seventh Avenue, New York City.

I am interested in membership in the Association. Please send me an application blank ....

I would appreciate a sample copy of the American Journal of Public Health.....

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Transactions of the International Conference on Sanitary Engineering, London, 1924

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THE CONTENTS cover a wide variety of subjects, including State Sanitary Administration; Works for the Prevention of Malaria and Yellow Fever; Methods of Disposal of Sewage and Trade Wastes in Various Countries; Treatment of Sludge Arising from the Agitation Processes of Sewage Disposal; Fertilizing Value of Sewage Sludge; Sewerage and the Control of Storm Water; Design of Sedimentation Works; House Sanitation; Refuse Collection and Disposal; National Control of Water Sources. *Price, $4.00*

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—or a metal pipe

(1) lined & (2) ENCASED in

(3) REINFORCED

CONCRETE?

LOCK JOINT

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Concrete Pipe

for Higher Heads

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MAKE YOUR CAST IRON JOINTS

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LEAD-HYDRO-TITE

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AND CUT YOUR EXPENSES

50% FIRST COST
50% SMALLER BELL HOLES
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100% CALKING

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WARM EARTH SURFACE
RADIATING
TEMPERATURE IS MODERATED AND EQUALIZED INSIDE BOX
VITRIFIED EARTHENWARE OR CONCRETE BOX BODY

Have you investigated the CLARK METER BOX, for absolute protection to the meter from freezing?

DEMONSTRATED by thirty years of use in thousands of cities.

A few of the most important reasons for standardizing on the placing of meters at the curb line in CLARK METER BOXES are—

1. Meter is always accessible. Consumer not at home or indisposed need not interfere with the efficient operation of meter department. No crawling under crates, kindling, etc. No flashlight required.

2. Meter is read whenever desired without annoyance to consumer, nor danger from burglars gaining admission to the home under guise of meter reader.

3. CLARK METER BOXES are placed at a uniform distance from curb and property line. Meter reader can not miss them. Over one-half the walking distance saved.

4. TWENTY SECONDS is all the time required for reading meter, including locking box. FIFTY SECONDS for changing meter, accomplished by the one piece bronze constructed lock (always in operating condition) and coupling yoke.

5. Leaks in entire service line are detected and registered by meter, relieving department of service line upkeep.

6. Meter cannot be tampered with by unauthorized persons. Perfect lock is secure with a key of its own.

7. ABSOLUTE PROTECTION TO METER from FREEZING although it is raised in meter box to a convenient height. Double lid has been proven a fallacy by extensive use of the CLARK METER BOX in the coldest climates.

8. PROTECTION from fire, hot water and damage of any nature.

9. UNIFORM INSTALLATION for all sizes and makes whether placed in the sidewalk, boulevard or street.

10. PERFECT LOCK—designed for this severe service. One piece bronze constructed. Nothing to corrode or require oil.

11. THE CLARK METER BOX is the ORIGINAL Northern Meter Box.

Let us cooperate with you for efficient operation of the service and meter department

THE CLARK METER BOX

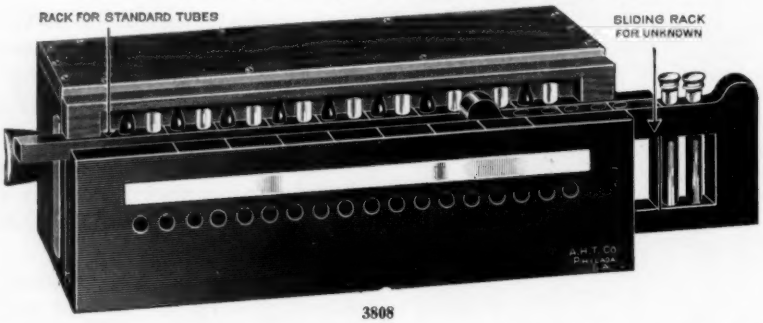
H. W. CLARK COMPANY

Manufacturers Water Works Equipment

MATTOON, ILLINOIS U. S. A.

ROBINSON HYDROGEN ION COMPARATOR

With arrangement providing diffused light of proper daylight value



3808

ROBINSON H-ION COMPARATOR, based on the colorimetric method and principles of Walpole (see *Journal of Biochemistry, Vol. 5, p. 207, 1910*) which consists of superimposing a tube of the colored solution over the color tube and comparing this combination with the tested solution plus an indicator superimposed upon a tube of distilled water.

The outfit consists of a substantial wooden box housing a color comparator and, behind it, a lamp house which provides illumination. The color comparator is composed of a stationary rack containing openings for nine pairs of tubes and a removable rack containing openings for four pairs of tubes. The movable rack slides easily in front of the stationary rack and can be so placed as to superimpose the tubes carried by it directly in front of those carried by the stationary rack. Observation holes are provided in a blackened screen in front of these racks.

The lamp house is illuminated by two 60-Watt Mazda lamps of tubular type and is separated from the comparator proper by a screen of ground glass in front of which is a screen of Corning Daylite glass, which arrangement provides diffused light of proper daylight value. This feature of constant illumination, both as to quantity and quality of light, insures comparable results irrespective of daylight conditions.

The comparator proper is finished in dull black, with the exception of a white strip of celluloid with matte finish placed above the observation holes and on which pH values can be written. The inside of the lamp house is painted white.

3808. Hydrogen Ion Comparator, Robinson, consisting of comparator with standard tube rack; sliding rack for unknown samples; three electric lamps 110 volts, 60 watts, 12 inches long by 1 inch diameter; ground glass screen and Daylite glass screen consisting of three sections. With working outfit consisting of eight standard comparison tubes, twenty-four rubber caps for same, two graduated pipettes for measuring indicator solution, nine ampoules of distilled water, a set of nine Color Standards with pH range 6.8 to 8.4, and a 100 ml bottle of standard indicator solution Phenol Red. With directions for use..... **$61.00**

Code Word..... *Dypgy*

NOTE—Color Standards with pH range 6.8 to 8.4 and standardized indicator solution Phenol Red are included in above outfit as this is the range usually required in bacteriology. Other ranges supplied on request.

Copy of Supplement No. 77 with detailed description and complete directions for use, sent on request

Sole Distributors

ARTHUR H. THOMAS COMPANY

RETAIL—WHOLESALE—EXPORT

LABORATORY APPARATUS AND REAGENTS

WEST WASHINGTON SQUARE **PHILADELPHIA, U. S. A.**

CABLE ADDRESS, "BALANCE," PHILADELPHIA

Neptune Trident Meters

Built for Accuracy and Durability

A WATER meter is either a perfect measuring instrument, or it is not. A meter must be of the highest standard in every detail of construction to withstand the exacting requirements of its service, or it will prove an unprofitable investment.

Neptune Trident Meters are mechanically correct water-measuring instruments—due to engineering skill in design, quality of materials used in every unit, and 100 per cent precision methods in manufacture.

Trident Meters are built to render accurate, dependable service in the measuring and conservation of water—to guarantee a maintenance economy that cannot be equalled, over a long period of years. The cost of Trident Meters is an investment assuring definite dividends and savings.

Before you select a meter, study the results in any city where Tridents are in use. This will convince you that Trident Meters are the standard in their field.

AQUAFAX is a 56-page, monthly magazine giving current news and accurate information regarding the conservation of water. The regular subscription price is $3.00 per year, but it will be sent free upon request to engineers, municipal heads and civic organizations.

Send for a copy of the 86-page book illustrating and describing all types and sizes of Neptune Trident Meters.

NEPTUNE METER COMPANY

Pioneers in Meter Progress

50 EAST FORTY-SECOND STREET, NEW YORK CITY

NEPTUNE METER CO., LTD., 1197 KING ST., WEST, TORONTO, ONT.

Boston	**San Francisco**	**Los Angeles**	**Portland**
Chicago	**Atlanta**	**Seattle**	**St. Louis, Mo.**

SULPHATE OF ALUMINA

MANUFACTURED BY

THE JARECKI CHEMICAL CO.

CINCINNATI, OHIO

FOR FULL PARTICULARS APPLY TO

ISAAC WINKLER & BROTHER, Sole Agents

CINCINNATI, OHIO

TYPHOID TOLL

BY

GEORGE A. JOHNSON

A Few Copies Still Available at the Secretary's Office

Established 1849

Bingham & Taylor

Buffalo, N. Y.

Patentees and Manufacturers of the original Buffalo Pattern Screw Type Adjustable Service, Roadway and Valve Boxes, and all subsequent improvements

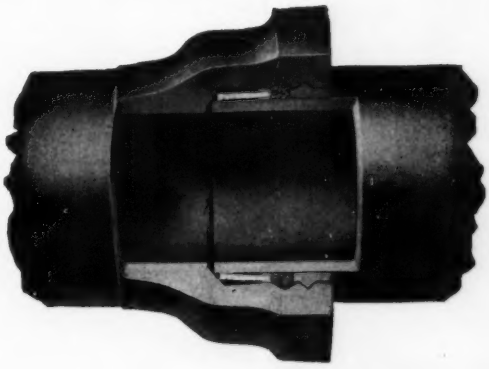
Write for descriptive booklet and any particular information desired

Bingham & Taylor

W. P. Taylor Company, Successor

Buffalo, N. Y.

Let Us Make Your Pipe Joints



Acipco Bell and Spigot Prepared Joint cast iron pipe has the following advantages:

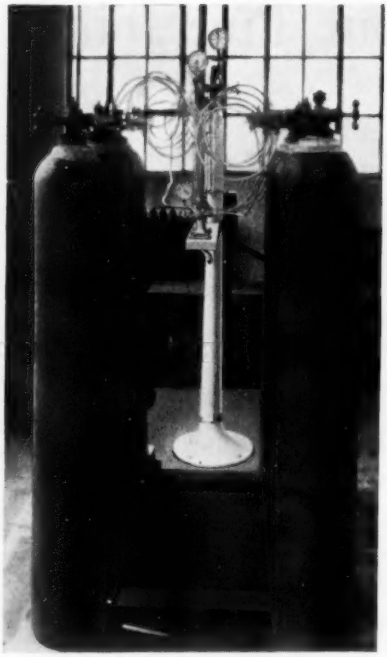
1. Joint is made at our foundry.
2. Delivered with joint materials in bell.
3. Main is laid by inserting spigot into bell containing joint materials.
4. Calking is done in the trench in usual way.
5. Made in sizes 4″ to 12″ inclusive, 16′ long.
6. Design and construction of joint causes tightening if deflected.

Any quantity, one piece or a carload, shipped immediately. Telephone, wire or write

AMERICAN CAST IRON PIPE COMPANY
BIRMINGHAM, ALA.

BRANCH OFFICES IN PRINCIPAL CITIES

PARADON *at Buffalo*



Installation of Paradon Ashokan Type for the Buffalo Water Department

Buffalo will soon complete one of the foremost filter plants in America.

Recently they needed an additional chlorinator. (Of course like most progressive cities Buffalo has been using chlorinators for years.)

Thorough investigation revealed the exceptional merits of the PARADON Chlorinator.

Result—a PARADON Ashokan type large capacity chlorinator was recently installed, this installation being similar to PARADON installations on such water supplies as those of New York City, Detroit, St. Paul, Wilkes-Barre, Baltimore, etc.

Doesn't the PARADON merit your investigation?

Send for our latest bulletins

PARADON ENGINEERING COMPANY

Specialists in Chlorinating Apparatus for Water, Sewage and Swimming Pools

27 SOUTH WASHINGTON PLACE LONG ISLAND CITY, N. Y.

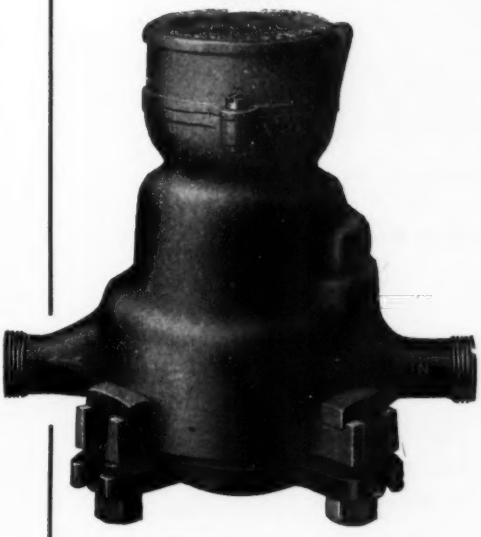
Visit the American Water Works Convention at Buffalo, June 7–11 and while there inspect the PARADON installation.

WATER METERS

DISC - CURRENT - COMPOUND

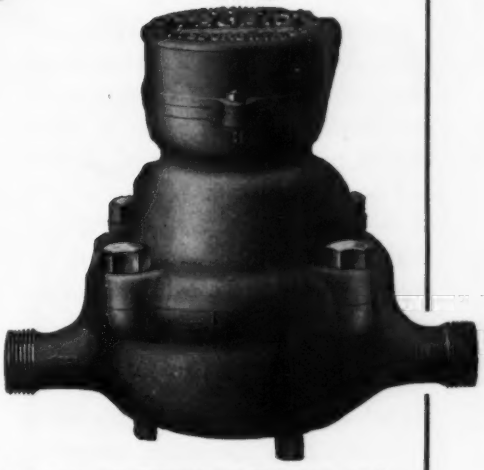
For Every Kind of Service

ARCTIC



The ARCTIC — a domestic service meter of the disc type, equipped with a cast iron bottom plate. This meter is especially designed for cold sections of the country but is adapted to warm sections as well.

TROPIC



The TROPIC—An all bronze domestic service meter of the disc type, with the connection spuds attached to the lower case. This meter is especially designed for warm sections of the country.

These two meters are identically the same excepting for the slight changes necessary to equip the ARCTIC with the frost breaking bottom plate.

Both the ARCTIC and the TROPIC will be equipped with a COMPLETELY ENCLOSED intermediate train RUNNING IN OIL, if desired

Write or wire nearest office for full and complete information

Please note change of address

PITTSBURGH METER COMPANY

General Office and Works: 7800 Susquehanna St., Pittsburgh, Pa.

SALES OFFICES:

New York, 50 Church Street
Chicago, 612 North Michigan Avenue
Kansas City, Mutual Building
Columbia, S. C., 1433 Main Street
Seattle, Wash.
Los Angeles, Union Bank Building

Oily condensate before and after passing through a Permutit Oil Removing Filter. Note crystal clearness of the filtered water.
(From an unretouched photograph)

Crystal Clear Water from Permutit Oil Removing Filters

Permutit Oil Removing Filters are guaranteed to remove all oil from water whether it is in suspension or emulsion. Oily condensate is transformed to water as clear as crystal and perfect for boiler feed at a cost of less than 2 cents per 1,000 gallons. Furthermore, it is not necessary to renew the filtering material from time to time as in all other types of oil filters.

Permutit Oil Removing Filters consist of a steel pressure filter filled with specially selected material. Under ordinary operating conditions the filters are washed every 24 to 48 hours and are scoured once a month, by means of the operating valves located on the apparatus.

All operations are controlled by the valves on the front of the filter and can be done by one man unaided in less than an hour. No loss of filtering material takes place, and many of these filters have been in operation for years without replacement.

It will pay you to look into this subject further. Write for our valuable booklet, "Saving Fuel and Repairs with Oil Free Water." No obligations—do it today.

Permutit
water softeners
Take all the hardness out of water

The PERMUTIT COMPANY - 440 Fourth Avenue - NEW YORK

IMPORTANT

THE Association has run short of certain numbers of the Journal. Any members who are not interested in preserving their back numbers for January and March, 1920 and 1922, and January, March, May and July, 1924, and are willing to return same, will be acting to the benefit of the Association.

AMERICAN WATER WORKS ASSN.,
170 Broadway,
New York City.

ADVERTISING

in this

JOURNAL

means more

BUSINESS

The **HISTORY** *of* **VENTURI** *No.* **1**

FOR ages man struggled to solve the apparently simple problem of the flow of a stream of water.

Back in the glorious Roman days, some 1800 years ago, water was sold from the great aqueducts by letting it run through a short, straight tube, or "measuring pipe", as it was called, to each consumer.

Unquestionably the Romans realized that the pressure affected the quantity of water supplied, but they, took no account of this fact. Therefore the consumers near the source of supply obtained, for an equal price, more water than their neighbors farther down stream.

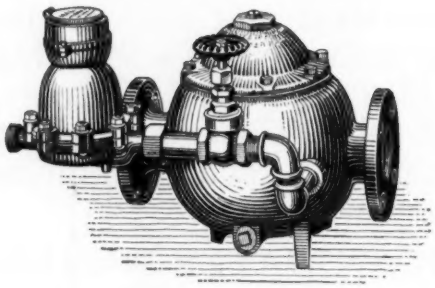
Some attempt even was made by the Water Department of the city to control the amount used and curb the theft of water by consumers.

At the completion of the Empire's downfall, however, the laws of flowing water still remained unfathomed.

Today the Venturi Meter stands guard over the water supply of thousands of towns and cities throughout the world —showing the amount of water furnished daily —immediately disclosing pipe line breaks and other wastage—checking the performance of pumps—recording the hourly day and night rates of consumption—controlling the rate of filtration—guiding sewage disposal—furnishing reliable data for future water provision, etc.

BUILDERS IRON FOUNDRY, Providence, R. I.

Toledo, Ohio, Invested $2730.00



Increased yearly income $20,471.32

As a result of installing Union Compounding Valves, Toledo, Ohio, has proven once more the increased revenue of this valve.

The first installation was on twenty-three meters of various types, there being thirteen 3-inch, eight 4-inch and two 6-inch. The monthly average billings before compounding increased after compounding 106 per cent, or $20,471.32 based on one year. In every instance there was an increase, the highest being 608 per cent.

Union Compounding Valves stop the leaks in revenue by measuring the small flow. For comparatively small initial investment you can secure returns in increased revenue that will astonish you. Write for catalog.

UNION WATER METER CO.

Established 1868

WORCESTER, MASS.

New York Office: 50 Church St. Philadelphia Office: 539 Real Estate Trust Bldg.

BYERS PIPE

GENUINE WROUGHT IRON

For Service Lines

After thirty, forty, fifty years of uninterrupted operation, whole installations of Byers Pipe, used for service lines and for water supply generally, have been dug up or taken out of old buildings, and found almost as good as new.

Byers Pipe, today, as for sixty years past, is made of genuine wrought iron—the metal whose rust resisting qualities are universally recognized by critical pipe users. That is why Byers is so extensively used and preferred by engineers and superintendents of wide experience.

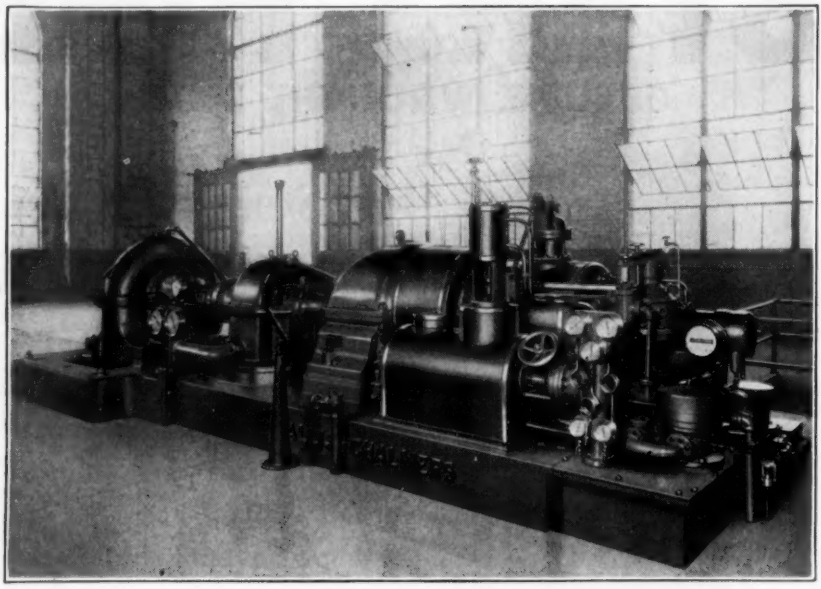
Genuine wrought iron pipe, from County Jail and Criminal Court Bldg., Chicago, in perfect condition after 44 years' service.

A. M. BYERS COMPANY

PITTSBURGH, PA. Established 1864

Distributors in all Jobbing Centers

Look for the SPIRAL STRIPE painted on Every Length of Byers Pipe; also NAME and YEAR rolled in metal



NOTICE THE SUBSTANTIAL CONSTRUCTION

This construction with moderately stressed parts and improved design give the sustained high economies for which Allis-Chalmers pumping equipment is noted. The fifteen million gallon per day geared Steam Turbine driven Centrifugal Pumping Unit shown recently installed for the City of Grand Rapids, Michigan, exceeded the guaranteed duty in official test by nearly seven per cent.

ALLIS-CHALMERS
MANUFACTURING COMPANY
Milwaukee, Wisconsin, U. S. A.

CEMENT LINED
SERVICE PIPE

Does not depend on water pressure to hold it in shape.

Is not injured by careless handling or back-filling.

Uses standard fittings.

Sixty years use proves it rustless.

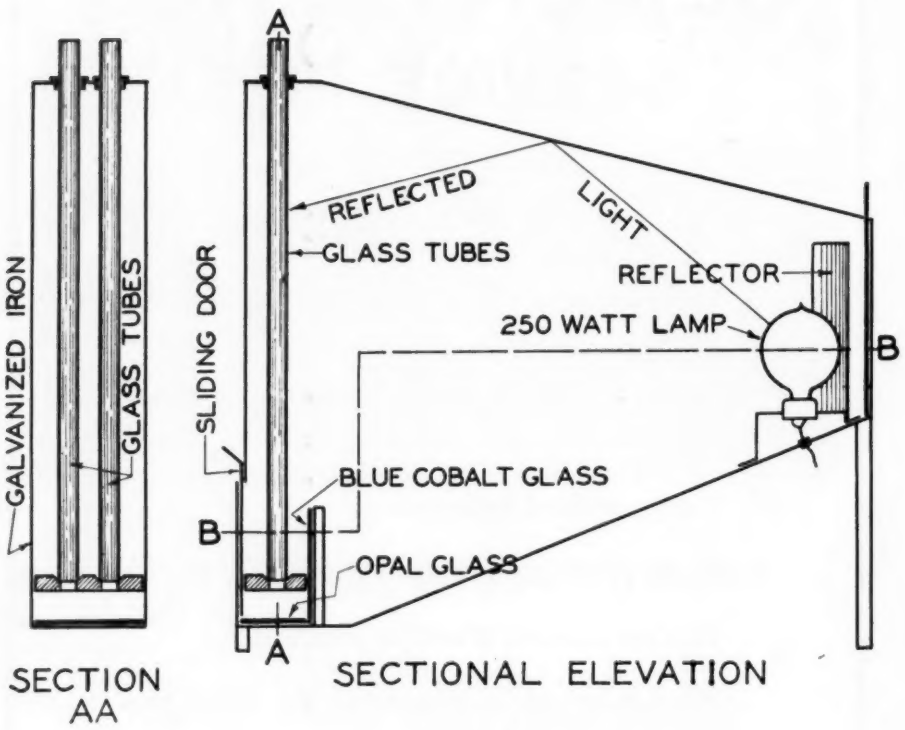
Has no harmful effect on any water.

Now standard in dozens of the most progressive cities and towns.

Inexpensive.

CEMENT LINED PIPE CO.
LYNN, MASS.

New Baylis Turbidimeter, for Accurate Measurement of Low Turbidity



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LEVITT FERGUSON COMPANY

Dealers in

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GLASS BLOWING TO SKETCH

1828 Greenmount Avenue **Baltimore, Md.**

NEW YORK OFFICE

DON'T FORGET

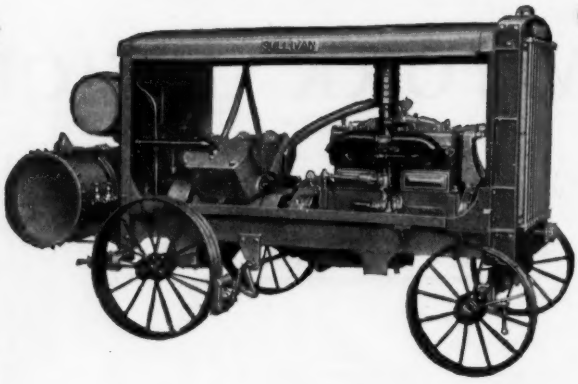
that the Association has headquarters in New York City, where we are ready to be of service to members when possible. When in the City call at the office and make it your headquarters. Have your mail directed there if you have not made hotel reservations, and then come to the office for it, or advise where you wish it sent. Jot the address and telephone number down in your note book NOW, so as to have it when needed.

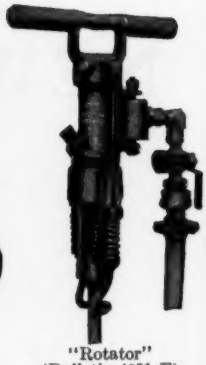
AMERICAN WATER WORKS ASSOCIATION

170 Broadway **Telephone Cortlandt 7718**

Speed Your Extension Work with Air Power

Clay Spader Bulletin 4281-J





"Rotator" (Bulletin 4281-F)

A SULLIVAN PORTABLE AIR COMPRESSOR

and Sullivan air power tools will aid your spring construction and extension work enormously. You'll find them wonderfully economical of time and labor in digging trenches, breaking pavement, cutting manholes, and in countless jobs in and around your plant, involving rock drilling, concrete removal, clay digging, light hoisting and hauling, driving sheet piling, spray painting, etc.

Sullivan Portable Compressors are sturdy, reliable units, driven by Buda, tractor type 4-cycle, 4-cylinder engines. They are available in 110, 170, 220 and 320 cu. ft. capacities. Steel wheels, rubber tires, skids or motor trucks are used as mountings. A Fordson-driven rig (120-cu. ft.) and electric motor operated units may be had, also.

Why not send for our booklet "Speed Up With Air."

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